HYDROGRAPHIC MANUAL

Publication 20-2

By Karl B. Jeffers

U.S. DEPARTMENT OF COMMERCE
Frederick H. Mueller, *Secretary*

COAST AND GEODETIC SURVEY
H. Arnold Karo, *Director*

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FIGURE 1.—Coast and Geodetic Survey Ship SURVEYOR. The SURVEYOR was commissioned in 1960 and has an overall length of 292 feet, a beam of 46 feet, and full load draft of 16 feet. She is fully equipped with modern hydrographic and oceanographic surveying instruments. Her normal complement is 14 officers and 90 men.

U.S. DEPARTMENT OF COMMERCE
Luther H. Hodges, Secretary

COAST AND GEODETIC SURVEY
H. Arnold Karo, Director

April 1, 1963

CHANGE NO. 1

to

C&GS PUBLICATION 20–2

HYDROGRAPHIC MANUAL

Third (1960) Edition

Change No. 1 (April 1, 1963) supersedes and/or replaces Provisional Changes 1 through 8 of 3/20/61 to 1/10/63. Revised, reprinted, or new pages in this packet are listed below.

III—Change 1	1—Change 1	27—Change 1	95—Change 1
IV—Blank	2—Change 1	28—Reprint	96—Reprint
IVa—Change 1	5—Change 1	65—Reprint	103—Change 1
IVb—Blank	6—Change 1	66—Change 1	104—Reprint
IVc—Change 1	13—Reprint	81—Change 1	127—Reprint
IVd—Blank	14—Change 1	82—Reprint	128—Change 1
V—Change 1	17—Change 1	91—Reprint	129—Change 1
VI—Blank	17a—Change 1	92—Change 1	130—Reprint
VII—Change 1	17b—Change 1	93—Change 1	143—Change 1
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CORRECTIONS TO THE HYDROGRAPHIC MANUAL

This manual will be maintained by issuance of corrections and/or addition of new material as necessary. Changes shall be inserted in the proper places upon receipt, and a record of such entry shall be made in the spaces provided below.

Change No.	Date of change	Date entered	Signature of person entering change
1	4/1/63		

MINOR CORRECTIONS.—These are changes which do not warrant replacement of complete pages. Identifiers at beginning of each correction indicate page number, line count from top of page, left or right column, and in parenthesis the first word of book line being corrected.

Page 9.—Line 7/Left (possible): Delete both commas.

Page 12.—Line 47/Right (recorded): For "twice" read "three times".

Page 40.—Line 14/R (as 23:00): For "or" read "of".

Page 65.—Line 5/L (matly 3): For "matly" read "mately".

Page 110.—Line 27/R (Meter): Delete "1952 Edition".

Page 122.—Line 19/R (surmounted): For "flatstaff" read "flagstaff".

Page 141.—Line 15/L (400 meters): For "or" read "of".

Page 142.—Line 30/L (shall): For "Ocassionally" read "Occasionally".

Page 150.—Line 28/R (vey data): For "ligible" read "legible".

Page 157.—Line 8/R (istance): For "istance" read "istence".

Page 180.—Line 6/L (arm): For "paper)" read "paper;".

PREFACE

This 1960 edition (C&GS Publication 20–2) of the Hydrographic Manual is issued as a guide to efficient execution and processing of hydrographic surveys. Present edition supersedes the 1942 edition (Special Publication 143) and Hydrographic Instructions 1 through 13 of 10/8/54 to 3/19/58. Although obsolete in many respects, particularly as regards rapid developments in control systems and echo sounders, the 1942 edition is still an excellent reference work and existing copies should be preserved.

The subject matter in this manual is identified by a numbering system in which the first number identifies the chapter and the second number identifies the section in the chapter. Cross references are entered by numbers in the same manner; for example the notation (see 1–26) refers to Chapter 1, Section 26.

This edition of the Hydrographic Manual has been compiled with the assistance and advice of many officers and personnel in the office and the field. Special credit is due Mr. G. F. Jordan who wrote the first draft of Chapter 6. The Smooth Sheet; to Mr. R. H. Carstens who reviewed a large part of the manual and contributed much valuable information; to personnel from the Electronics Laboratory for their contributions to Chapter 3; to the officers who reviewed the manuscript; and to Mr. C. E. Cook for his assistance in preparing the index.

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1. GENERAL REQUIREMENTS

1–1 Introduction.—To provide charts and related information for marine and air commerce, and to provide basic data for engineering and scientific purposes, and for other commercial and industrial needs, the Coast and Geodetic Survey is authorized by law to conduct a variety of field and office activities. These include topographic surveys of the coastline and hydrographic surveys of United States and Territorial waters. This manual is intended to describe the field operations required to accomplish hydrographic surveys. Field methods and standards which are adequately described in other Bureau manuals are not covered in this manual except by appropriate references.

The publication of an adequate series of accurate nautical charts is undoubtedly the Government's greatest single contribution to safety at sea and the growth of the merchant marine and other waterborne activities. There are those who believe that hydrographers make a fetish of accuracy in survey operations, that many unnecessary refinements are attempted, and that some of the final results are only "paper accuracies." Few mariners attempt to evaluate a nautical chart. They have a simple faith in its accuracy. Where no dangers are shown they believe that none exist. The hydrographer by patient and relentless attention to every detail must justify the mariner's boundless confidence in his work.

Fundamentally, hydrographic surveying is that branch of physical oceanography employed to define the configuration of the bottom of oceans and navigable waters of lakes, rivers, and harbors. In a much broader sense, the science embraces a wide variety of activities, all of which are necessary for compilation of nautical charts and related publications designed to provide all information required for safe navigation.

1–2 Nautical charts.—The most important criteria by which the value of a nautical chart may be judged are its accuracy, adequacy and clarity. A lack of any one of these may result in a marine disaster with consequent loss of life and property. Except for blunders in compilation, accuracy depends directly on the quality of field surveys; the hydrographer and cartographer are equally responsible for the adequacy, but the cartographer alone can embody clarity in a chart.

Accuracy of a nautical chart is dependent on the accuracy and adequacy of the hydrographic surveys from which it is compiled; it cannot be more accurate. The increasing size and draft of merchant vessels, growth of submarine activity, and recent developments in exploitation of submerged lands are combining to make the standards for hydrographic surveying ever more strict. In recent years new surveying and navigational equipment have been devised and former ones developed to greater perfection. Hydrographers must be alert to keep abreast of advancing electronic and other scientific developments which can be adapted to survey uses.

While the need for greater accuracy and detail in the deeper waters is becoming more and more apparent, so too is the need for greater attention to the inshore details and areas of shallow depths. The number of small boats in use has grown enormously, giving rise to an unprecedented interest in all manner of areas being explored by these part-time mariners, areas that were formerly of relatively little interest.

Hydrographic field parties should be alert to every opportunity for field-checking the charts, bearing in mind the requirements of every type of chart user, from small boat to supertanker to submarine. Every instance where an improvement can be made should be reported, supported if possible by sufficient information to effect the improvement. Of all chart users, hydrographic parties are unique in their opportunity and ability, not only to judge the accuracy and clarity of our nautical charts but also to take effective steps toward improvements.

1–3 SPECIFICATIONS FOR HYDROGRAPHIC SURVEYS.—This part of the manual summarizes general specifications for hydrographic surveys. Detailed discussion of individual subjects will be found in later parts of this manual or in other C&GS manuals.

1–3a Project instructions.—The field operations required for the hydrographic survey of a specified area are assigned a project number such as OPR–406, the letters identifying the project with Operations Division, Office of Oceanography. The numbered project instructions supplement the general instructions in this and other manuals, and their content varies from specific detail to generalized manual-compliance depending on locality and nature of project. Instructions for combined-operation projects usually include such subjects as project limits, control, topography, hydrography, tides, Coast Pilot, magnetic observations, and miscellaneous; occasional added subjects are special oceanographic investigations, current observations, and wire drag. See Chapter 2.

1–4 Data to start survey.—Copies of all prior survey data that are considered necessary in connection with the combined operations of the project will be furnished with the project instructions. These will include: descriptions and geographic positions of all triangulation stations and recoverable topographic stations; copies of prior hydrographic and topographic surveys; descriptions and elevations of tidal bench marks; and information as to dangers reported. If prior photogrammetric surveys have been made, copies of the manuscripts and photographs will be furnished.

1–5 Presurvey review.—The Chart Division will prepare a presurvey review for each hydrographic survey project (see 6–108). All prior records and the largest scale charts of the project area are examined. Critical soundings and charted data which are unverified or questionable will be indicated and described on the charts. All items must be thoroughly examined in the field to prove or disprove their existence, and each item shall be specifically mentioned in the descriptive report to accompany the survey. The presurvey review is not intended to relieve the Chief of Party or the hydrographer from a responsibility to compare the results of the survey with the features shown on the largest scale chart of the area.

1–6 Scale of surveys.—One of the rules of chart construction is that data on a smooth sheet shall seldom, if ever, be enlarged to the scale of a published chart. The scale adopted for a survey shall be larger than—preferably at least twice as large as—that of the largest-scale published or proposed chart of the area.

The basic scale for hydrographic surveys of the Coast and Geodetic Survey is 1:20,000 and almost all other scales used have a simple relationship to it. No inshore survey adjacent to the coast shall be plotted on a scale smaller than 1:20,000, except by authority of the Director.

All important harbors, anchorages, restricted navigable waterways, and many parts of the coast where dangers are numerous shall be plotted on scales of 1:10,000 or larger.

1–7 Sheet Layout.—Prior to beginning field work, a hydrographic sheet layout (Figure 2) shall be prepared and forwarded to the Washington Office for record and approval. The layout should generally be made at the scale of the largest scale chart covering the project area. Each sheet should be laid out to include as large a water area as practicable, at the same time providing for adequate overlap with adjacent sheets and ensuring that all required control stations will be included (see 2–20). The overlaps of sheets should be such that soundings will seldom be plotted closer than 3 inches to the edge of a sheet.

Sheets containing small detached areas of hydrography shall be avoided if practicable. This can usually be accomplished by placing a subplan, or inset, on the smooth sheet at the same or an enlarged scale (see 6–6).

All hydrographic sheets shall be laid out so that the projection lines are approximately parallel with the edges of the sheet, except when such a layout is extremely uneconomic or impractical. Skewed projections should not be used without prior authority of the Director.

1–8 Sheet sizes.—The standard size for all hydrographic smooth sheets is 36 by 54 inches. Chiefs of Party are authorized to increase the size of the sheet to 36 by 60 inches in exceptional cases, but approval shall be obtained from the Director before using a larger sheet. The maximum size,

1–13 Field numbers.—For convenient reference while a survey is in progress, each hydrographic sheet shall be assigned a field number. A permanent field number shall not be assigned to any sheet until hydrography is started on the sheet; and the number shall not thereafter be changed even though the survey is completed by another vessel. Unused boat sheets constructed by or for one survey unit and subsequently transferred to another unit shall be assigned a field number by the latter when the survey is started. The final two digits of the field number represents the calendar year in which the survey was initiated and are not to be changed if the survey extends into the following calendar year.

The field number shall be a hyphened combination of letters, which identify vessel or party starting the survey, and numbers that indicate scale of survey, sequence of survey (regardless of project number) in vessel's current series at that scale, and year in which survey was started. Examples follow.

EX–2.5–1–58 EXPLORER — scale 1:2,500—first sheet in the series at that scale—survey begun in 1958.

ECFP–10–11–59 = East Coast Field Party —scale 1:10,000—11th sheet—1959.

LJ–25–2–60—LESTER JONES = scale 1:25,000—2nd sheet—1960.

PI–200–4–60 = PIONEER—scale 1:200,-000—4th sheet—1960.

Completed surveys are normally referred to by their registry numbers in correspondence

1–14 Registry numbers.—At the end of each season, or at such times as circumstances dictate, the Chief of Party shall request from the Washington Office the assignment of registry numbers to completed hydrographic surveys, or surveys which will be completed during the season. Numbers should not be requested for incomplete surveys.

1–15 Horizontal control.—The control for all hydrographic surveys, except track line and reconnaissance surveys, shall be based on triangulation of third order accuracy or higher (see 4–1). All established triangulation stations in a project area shall be searched for and appropriate reports submitted. If new triangulation is required, the field work shall be accomplished in accordance with instructions and specifications contained in Special Publication No. 247, Manual of Geodetic Triangulation. Points selected for the location of electronic shore stations shall be located by triangulation or traverse of third order accuracy or higher.

1–16 Photogrammetric surveys.—Nearly all topographic surveys are now being made photogrammetrically, and the hydrographic party will be furnished photographs, manuscripts, and other data to support hydrographic operations. Except in Alaska and other remote areas, the Photogrammetry Division will accomplish all field work required to produce advance manuscripts, and, in most cases, will assign a photogrammetrist to build and locate signals to provide visual control for hydrography.

Outside continental United States, hydrographic parties shall establish and identify control and accomplish the field inspection required in advance of photogrammetric compilation. On occasion the party may be furnished preliminary manuscripts which are based on office identified control. See Chapter 4 for a discussion of manuscript classifications and uses.

A marked triangulation station can seldom be identified on a photograph and substitute points in the immediate vicinity are used. (See Photogrammetry Instruction 22, Revision 1, dated 1 November 1959.) At least two such points should be identified and pertinent information recorded on a Control Station Identification (C.S.I.) card (Form 152). Identification must be precise, as misidentified control will warp the compilation and will seriously affect the location of the supplemental photo-hydro stations (see 4–11).

Supplemental control for hydrography shall be located by photogrammetric methods wherever practicable (see 4–18). The stations shall be established in accordance with Photogrammetry Instruction 45, Revision 1, dated 15 March 1954. Discrepancies in the location of photo-hydro stations should not exceed 0.5 mm. at the scale of the manuscript.

The Photogrammetry Instructions referred to in this section are part of a series which cover field operations in photogrammetric

surveys. A new Topographic Manual, Part 1, will eventually replace them.

1–17 Planetable surveys.—Instructions for planetable surveys are contained in the Topographic Manual, Special Publication No. 144. Topographic surveys by planetable methods will seldom be required; however, the planetable shall be used to locate signals for control of hydrography wherever expedient to supplement the photogrammetric work (see 4–9). When stations are located by planetable, 90 percent of them shall be within 0.5 mm. of their true geographic positions and no station shall be in error by more than 0.8 mm. as measured on the topographic sheet.

All graphic control and other planetable surveys shall be made on 24 by 31-inch aluminum-mounted sheets as furnished by the Washington Office. The scale of the survey shall never be smaller than the largest scale hydrographic survey of the same area.

1–18 Signal location by sextant angles.—On occasion it is necessary to locate a signal by sextant angles (see 4–26). In such cases the position of the signal shall be determined by (1) a three-point fix at the station with a check angle; or (2) three sextant cuts giving a good intersection. The geographic position of the station should not be in error by more than 1.0 mm. The strongest available fix should always be used and should include triangulation stations where practicable. Stations located by sextant angles shall not be used to locate other stations.

1–19 Electronic control.—Stations shall be so placed that distance arcs in area to be surveyed will intersect at angles of not less than 30° or more than 150°. Antennas of electronic-system shore stations shall be placed over triangulation stations or reference marks or shall be located by triangulation or traverse of at least third-order accuracy. Newly established antenna positions shall be permanently marked, where possible, by standard disks and described. Electronic control stations usually are assigned three- or four-letter names; name and date shall be stamped on new disks only. An electronic control station which is placed near an existing triangulation station shall be marked and described as a new station; data on this new mark shall also be added to recovery description of triangulation station. Records, computations, and descriptions of electronic control stations shall be forwarded to Washington Office with other geodetic records.

(a) Shoran is a line-of-sight system and should rarely be used at greater distances (see 3–33 to 47). The system requires very careful and repeated calibration. At least one calibration for each ground station shall be obtained for each 5 consecutive days. Calibrations shall be obtained at various distances including the minimum and maximun distances used in hydrography. Whenever changes are made in the equipment, the time of change must be recorded and new calibrations observed. A zero check shall be observed and recorded at each calibration, at the beginning and ending of each day's work, and at intervals of 1 to 2 hours while surveys are in progress. Special manuals are provided containing instructions for installation and servicing of Shoran equipment.

(b) EPI equipment is designed for use on large survey ships to control offshore hydrography at maximum ranges of about 500 nautical miles (see 3–23 to 32). It shall not be used to control surveys at a scale larger than 1:100,000. The equipment shall be calibrated at the beginning and end of each trip, when changes are made in the equipment, after each period when the equipment is not in operation, and at other convenient times. Detailed instructions for the operation and maintenance of EPI equipment are contained in Special Publication No. 265A, EPI Manual.

(c) The standard Raydist equipment is designed for use in survey vessels of any size larger than launches (see 3–48 to 61). A smaller transistorized equipment can be used in small survey boats. Raydist may be used to control surveys at any scale normally used by the Bureau. The phasemeter dials must be set at a known position. Partial lane corrections to measured distances shall be applied when they can be plotted at the scale of the survey. The lane count must

frequency to obviate the necessity of applying velocity corrections (see 5–120). The frequency meter reading shall be recorded at least once each hour. Bar checks shall be recorded twice daily when circumstances permit.

On large vessels where bar checks are not practicable, vertical cast comparisons shall be made and recorded at selected intervals when good casts can be obtained.

1–37 **Fathograms.**—Stamp No 31 shall be impressed at the beginning and end of each fathogram and all required information recorded to identify the record with the survey. Position fix marks shall be numbered consecutively and the day letter shown at every tenth position. Positions where the line begins, breaks, or turns about should be indicated (see 5–31). The phase or scale being used shall be indicated at each change. The PDR phase changes are automatic with base scales in multiples of 400 fathoms. The base must be indicated on the fathogram as 0 plus, 400 plus, 800 plus, etc.

Fathograms may be folded in accordion style or filed in rolls. The first method is preferred (see 5–32).

1–38 **Depth units.**—The depth unit of hydrographic surveys in the Atlantic Ocean, Gulf of Mexico and bodies of water tributary thereto shall be integral feet except for those offshore surveys which are entirely beyond the limits of charts whose depth unit is feet, in which case the depth unit of the survey shall be fathoms. In certain areas, such as the coast of New England, where echo sounders are operated on the fathom scale for most of the survey, the boat sheets may be plotted in fathoms, but the smooth sheet shall be plotted in feet unless otherwise directed by project instructions.

The depth unit of hydrographic surveys in the Pacific Ocean and bodies of water tributary thereto shall be fathoms, except that where the major part of the survey is within the limits of a chart whose depths are in feet, the smooth sheet shall be plotted in feet.

Although the depths in the sounding record may change from one unit to another within the area of the survey or within the same sounding records, they are all reduced to the unit to be used on the smooth sheet. Only one unit, fathoms or feet, shall be used on any boat or smooth sheet.

Soundings shall be recorded in integers, or to the nearest decimal part, according to Table 2 and the following rules:

(a) Echo soundings with the 808 Fathometer or EDO 255 for a hydrographic survey to be plotted in feet shall be recorded in FEET and DECIMALS except for (b) and (c);

(b) Where 808 type graphic-recording instruments, which can be operated to record in either feet or fathoms, are used in areas of irregular bottom, the first phase in feet shall be used to its limit, but, where numerous changes in phase would be required on the foot scale, fathoms shall be used for greater depths;

(c) Where EDO 255 graphic-recording instruments, which cannot be changed from one mode to another at will, are used, the recorder shall be operated on the foot scale to the maximum practicable extent in areas charted in feet. In areas where depths exceed the limit of the foot scale or the submarine features are very irregular, the instrument shall be operated on the fathom scale.

(d) All depths measured by echo-sounders for a hydrographic survey to be plotted in fathoms shall be recorded in **fathoms** and decimals except for (e);

(e) Where practicable, the shoal water soundings obtained by echo-sounders for a survey to be plotted in fathoms shall be obtained on the first phase in feet.

(f) Wire soundings shall be recorded in **fathoms** and **decimals.**

(g) Hand lead soundings interspersed with echo soundings shall be recorded in the same unit as the echo soundings.

(h) Hand lead soundings in depths less than 11 fathoms and pole soundings shall be recorded in **feet** and **decimals.**

1–39 **Reduction of soundings.**—Recorded soundings must be corrected for any depart-

TABLE 2.—Units for recorded soundings and corrections

Character of area or bottom	Depth range	For soundings in feet: In protected waters: Record soundings to the nearest	For soundings in feet: In protected waters: Enter corrections to the nearest	For soundings in feet: In exposed waters: Record soundings to the nearest	For soundings in feet: In exposed waters: Enter corrections to the nearest	For soundings in fathoms: In protected waters: Record soundings to the nearest	For soundings in fathoms: In protected waters: Enter corrections to the nearest	For soundings in fathoms: In exposed waters: Record soundings to the nearest	For soundings in fathoms: In exposed waters: Enter corrections to the nearest
On dangers and shoals									
On navigable bars									
In dredged channels	*fathoms*	*foot*	*foot*	*foot*	*foot*	*fathom*	*fathom*	*fathom*	*fathom*
At critical places in natural channels	0–11	0.2	0.2	0.5	0.2	0.1	0.1	0.1	0.1
In inside routes									
For delineation of the low-water line									
Over regular bottom	0–11	0.5	0.2	1.	0.5	0.1	0.1	0.2	0.1
On the least depths in irregular bottom									
Elsewhere in irregular bottom	0–11	1.	0.5	1.	0.5	0.2	0.1	0.5	0.2
On shoals and banks	over 11	1.	0.5	1.	0.5				
Elsewhere		1.	1.	1.	1.				
On shoals and banks and over regular bottom	11–31					0.1	0.1	0.2	0.1
Elsewhere						0.2	0.1	0.5	0.2
Over regular bottom	31–101					0.2	0.1	0.5	0.2
Elsewhere						0.5	0.2	0.5	0.2
Everywhere	101–150					1.	0.5	1.	0.5
When soundings are obtained with EDO type depth recorder:									
Over regular bottom	150–600					2.*	1.	2.*	1.
See (a) below	150–600					5.	2.	5.	2.
Fast speed	600–1800					5.	2.	5.	2.
Slow speed, see Note below	over 600					10.	4.	10.	4.
When Precision Depth Recorder is used:									
Over regular bottom	150–600					2.	1.	2.	2.
On steep slopes						5.	2.	5.	2.
Elsewhere	over 600					5.	2.	5.	2.

* On fathograms with lines at 5 fathom intervals read soundings to nearest 2½ fathoms but drop half-fathoms, thus last unit on soundings shall be recorded as either 0, 2, 5, or 7.

(a) With steep slopes and where an independent or check reading of the fathogram will not often agree with soundings recorded to the above lesser interval.

NOTE: On steep slopes where independent or check readings of the fathogram will not often agree when read to 10-fathom intervals, it may be necessary to allow greater latitude in the checking of the soundings.

the area and the change in time and range of tide from place to place. If, on arrival at the working grounds, the selected sites are found to be impracticable, the Chief of Party may make necessary subsitutions, but he must inform the Office of such changes and the reasons for them (see 2–49 to 52).

Instructions for installation, maintenance and removal of tide gages are contained in Special Publication 196, Manual of Tide Observations. When practicable, observations at each secondary station shall be continued over a period of at least 29 days. The hourly heights of the tide required for reduction of soundings shall be tabulated before the marigrams are forwarded to the Washington Office. Hourly heights from standard gage rolls will be furnished by the Office on request.

The time meridian used should be clearly marked on the first marigram. When the observations at any station are terminated, a notation of the hour and date of discontinuance should be entered on the last marigram taken from the gage. The exact location of each tide station shall be shown on hydrographic sheets (see 6–71).

1–47 Current observations.—A current station is any specific location at which currents are systematically measured. Geographic positions of project current stations will be listed in the project instructions or will be indicated on an accompanying chart of the area. Observations shall be made as close as possible to the station sites specified.

The project instructions will also specify the depths at which observations are to be made, the number of hours (usually 100) of observations, and the groups of stations which are to be observed concurrently.

Velocity and direction of the current shall be determined with the best available instrumental equipment suited to the particular station. The project instructions will usually specify the equipment to be used, whether current pole and Price meter, the Roberts meter, or other types of meters. General instructions are outlined in the Manual of Current Observations, and instructions for use of the Roberts meter are in the Roberts Radio Current Meter Operating Manual.

To insure satisfactory meter operation, all meters shall be checked by pole observations. At least one series of three such comparisons shall be made at regular half-hourly meter readings, preferably bracketing a strength of current. Meter and pole observations must be simultaneous; special meter readings shall be made and recorded for pole observations which cannot be made on meter schedule. Any questionable meter performance indicated by the comparisons shall be investigated and corrected as soon as possible.

Unless modified by the project instructions, observations in charted depths of 35 feet or more shall be made at 1/6, 1/2, and 5/6 the depth but in no case shall the top meter be set deeper than 15 feet. In charted depths of 25 to 35 feet, observations shall be made at 1/6 and 1/2 the depth and at 6 feet less than charted depth. Observations in charted depths less than 25 feet shall be made at 1/3 and 2/3 the depth. Tidal changes need not be considered in determining depths of meters.

Current observations shall be made half-hourly for the full period specified in the project instructions except where modified in following paragraphs.

Previous instructions state that a station shall be terminated when the current does not exceed 0.4 knot during the first 25-hour period, and this rule shall still apply when the current is both weak and erratic. However, engineers and other scientists are interested in the water movement at low velocities, and much useful data will be lost if a station is automatically terminated when the current does not exceed 0.4 knot. Therefore, when a weak current exhibits a definite pattern such as uniform flow in one direction, repeating rotary action, or reversal of direction the station shall be observed for the full period stated in the project instructions.

If a series of observations is broken due to failure of equipment or to other causes, every reasonable effort shall be made to resume observations as soon as possible.

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Stations observed at only one depth.—In rotary currents, any period during which the meter has been inoperative shall be made up at the end of the series. In reversing currents, a break of less than 12 hours in the series of observations may be ignored and the series may be discontinued at the end of the specified period; if the break exceeds 12 hours, resumed observations shall continue through the unobserved part of the series plus an additional 25 hours. In general, observations shall be for the number of complete tidal days (25 hours each), not necessarily in succession, specified in the project instructions.

Stations observed at more than one depth.—A break of less than 12 hours in observations at one depth is not critical if an unbroken series is obtained at other depths. If the break exceeds 12 hours, observations shall continue at all depths as outlined for similar breaks in one-depth observations of reversing currents.

Groups of stations observed concurrently.—After a break in observations at any one station or depth, determine the additional period of observations as for a single station and continue observations at all stations of the group for the same additional period.

In order to obtain the maximum possible velocity from the current observations, the Commanding Officer shall make every effort to observe the current during the period of the month when astronomically the velocity should be at its strongest. In waters where there is a semidiurnal or mixed type of tide, the period of maximum velocity is near times of new or full moon (spring tides) at perigee (moon nearest the earth). Where the tide is diurnal, the maximum velocity occurs near the times of the moon's greatest north and south declinations. Astronomical data for a particular year can be obtained from any tide table or tidal current table for that year.

Dubious prospects of completing a full period of observations shall not be allowed to interfere with occupation of a station; any station occupied, even for a period less than that specified, will contribute to the oceanographic knowledge of the area. When adverse weather causes obvious distortions of plotted current data, station observations shall be discontinued until the return of normal weather.

Each station occupied shall be accurately located by sextant fixes or other acceptable means and plotted on a section of the largest-scale chart of the area. This chart section shall be attached to the first record book for the particular station.

When the Roberts Radio Current Meter is used, all current tapes shall be scaled and checked promptly on removal from chronograph or current-meter recorder. It is also important that observers properly mark all tape sections used in determining the velocity and direction of the current and the seconds of time. Do not discard tapes that show no velocity or direction signals because of equipment failure or because of a zero velocity at slack water. A tape for each entry in the log book shall be forwarded to the Washington Office.

The field party shall maintain a running plot of the half-hourly observations of current velocities and directions for each meter. Corrective measures shall be taken if any data appears questionable.

The observer must be thoroughly familiar with the chronograph and its operation if he is to obtain good tapes. The Roberts Radio Current Meter Operating Manual says that fast tape speed is required to permit good scaling of rapid signals (strong currents); slow tape speed is advised for slow signals (weak currents) to condense the record to convenient lengths.

The half-hourly velocities and directions observed at each depth shall be recorded on Form 270, Record of Current Observations. All record books, chronograph tapes, and plotted curves shall be forwarded to the Washington Office as soon as practicable after termination of each station.

If a survey vessel or current buoy is to be anchored in or near traffic lanes, the Commander of the Coast Guard district in which project is located shall be given advance notice and requested to publish same in his Local Notice to Mariners.

1–48 **Oceanography.**—Periodic measurements of temperatures and salinity are required to compute velocity corrections to echo soundings (see 5–114 to 118), except in areas where satisfactory bar checks can be obtained to the maximum depth of hydrography. The frequency of observations is a matter that must be left to the hydrographer's judgment, but it must be borne in mind that, to comply with the requirements, the average temperature from surface to bottom used to correct any sounding must be within 2 degrees of the actual mean temperature. At least one serial temperature and salinity should be observed in the deepest part of the area surveyed each month (see 3–116).

Nansen bottles and precision type reversing thermometers should be used when available and salinities determined on a salinity bridge. The Sigsbee water cup with hydrometers and the Tanner-Sigsbee reversing frame and thermometer shall be used when the heavier equipment is not available.

The project instructions may require oceanographic observations in addition to the temperature and salinity observations required for reduction of soundings. Repeat observations should be made during the season to provide data on seasonal changes. The program of observations at each station shall be in accordance with instructions contained in Chapter 2, H.O. Publication 607 and outlined as follows:

(a) Nansen-bottle samples at International depth intervals from surface to bottom or to a depth specified by project instructions. Salinity samples may be retained until time is available for their analysis.

(b) Bottom sample at all stations regardless of depth. Samples by Phleger Corer are preferred. All samples shall be retained for future analysis.

(c) Secchi disc readings.

(d) Sea and swell observations in accordance with H. O. Publication 606–e.

(e) Set and drift observations as determined by difference in position between beginning and end of observations, if practicable.

(f) Weather observations (see H.O. Publication 607, Figure C–8).

1–49 Bathythermograph (BT) observations.—When instructed to make bathythermograph observations, lowerings should be made at intervals of not more than 2 hours. Data from BT slides should be processed in accordance with procedures outlined in project instructions. General instructions for use of BT's are contained in H.O. Publication 607.

1–50 Aids to navigation.—All fixed aids to navigation established by the United States Coast Guard should be located by triangulation. A substitute method may be used if necessary, but the determination shall be such that no appreciable error will result. The azimuth of range lines shall be determined by triangulation if practicable.

The positions of and depths at all floating aids to navigation in the project area shall be determined by the hydrographic party. Floating aids should be located by sextant fixes, not cuts, with one or more check angles, and shall be fully described.

If a floating aid is found to be off station as shown on the largest scale chart of the area, the fact should be promptly reported to the Commander of the nearest Coast Guard District. If the aid is off station to an extent that a danger to navigation exists, the facts should be reported by dispatch. Any recommendations, based on new hydrographic surveys, for additional aids or for more desirable locations of existing aids, should be reported to the Coast Guard in writing as soon as practicable, with a photostat or tracing of the boat sheet. Copies of all correspondence with the Coast Guard shall be furnished the Washington Office (see 5–80).

1–51 Dangers to navigation.—All shoals, rocks, wrecks, etc., discovered, that are considered dangers to navigation, shall be reported immediately by radio, telegraph, or telephone to the Commander of the nearest U.S. Coast Guard District and to the Coast and Geodetic Survey District Office (see 5–72 and 7–23). A copy of the message shall be forwarded to the Washington office with a tracing from the boat sheet or chart showing the exact location of the danger.

1–52 Wire-drag investigations.—In many cases time can be saved by use of a wire drag to investigate indications of submerged dangers (see 5–124). When reported dangers or obstructions cannot be found by standard survey methods, the surrounding area should be wire dragged to prove or disprove their existence. Evidence to support a recommendation to delete charted dangers or obstructions must be conclusive. All wire-drag operations shall be conducted in accordance with the requirements of Publication No. 20–1, Wire Drag Manual.

1–53 Coast Pilot report.—All hydrographic field parties shall collect Coast Pilot information and furnish at the end of the season a special report on this subject for use in the revision of the Coast Pilot of the area (see 2–36). The report should be submitted in duplicate and should be a compilation of all such data collected by each unit of the survey party. If the information in the published Coast Pilots is correct and adequate, a statement to this effect should be included in the report.

1–54 Geographic names.—The hydrographic surveys should be the authority for all geographic names seaward from the high-water line, including the names of all water features such as channels, sloughs, rivers, inlets, bays; and those of the reefs, rocks, banks, and shoals therein; and all small islands and the names of geographic features thereon. It is particularly important that geographic names be correct not only as to name, but also as to spelling and application. Charted names and those in the Coast Pilots should be checked against local

TABLE 5.—Scale equivalents for laying out survey sheets

Scale	One inch equals		One centimeter equals		One nautical mile equals		One statute mile equals	
	Nautical miles	Statute miles	Nautical miles	Statute miles	Inches	Centimeters	Inches	Centimeters
1:2,500	0.034	0.039	0.013	0.016	29.165	74.08	25.344	64.37
1:5,000	.069	.079	.027	.031	14.582	37.04	12.672	32.19
1:10,000	.137	158	.054	.062	7.291	18.52	6.336	16:09
1:20,000	.274	.316	.108	.124	3.646	9.26	3.168	8.05
1:30,000	.411	.473	.162	.186	2.430	6.17	2.112	5.36
1:40,000	.549	.631	.216	.249	1.823	4.63	1.584	4.02
1:50,000	.686	.789	.270	.311	1.458	3.70	1.267	3.22
1:60,000	.823	.947	.324	.373	1.215	3.09	1.056	2.68
1:80,000	1.097	1.263	.432	.497	.911	2.31	.792	2.01
1:100,000	1.372	1.578	.540	.621	.729	1.85	.634	1.61
1:120,000	1.646	1.894	.648	.746	.608	1.54	.528	1.34
1:200,000	2.743	3.157	1.080	1.243	.365	.93	.317	.80
1:400,000	5.486	6.313	2.160	2.486	.182	.46	.158	.40
1:500,000	6.858	7.892	2.700	3.107	.146	.37	.127	.32
1:1,000,000	13.715	15.783	5.400	6.214	.073	.19	.063	.16

1 Nautical mile = 6,076.10 ft. or 1852.0 m.
1 Statute mile = 5,280 ft., or 1609.3 m.

tiplying the dimensions of the sheet by the number of miles at the selected scale. For example, a sheet 36 by 54 inches on a scale of 1:20,000 will include an area 9.8 by 14.8 nautical miles.

If planetable topographic or graphic control surveys are required, the location of the sheets should be shown in the sheet layout.

2–21 Sheet orientation.—All hydrographic sheets shall be laid out so that the projection lines are approximately parallel with the sides of the sheet, except when such a layout is extremely uneconomic or impracticable. The reason for this is that a cloth-mounted sheet distorts almost uniformly along its axes and if the sheet is laid out with the projection lines parallel to the edges, distortion is comparatively easy to compensate for in chart compilation. With a skewed projection it is much more troublesome and, in addition, such a sheet is inconvenient to handle. North shall always be considered the top of the sheet, whether or not the projection lines are parallel to the edges of the sheet.

2–22 Sheet sizes.—The standard size for all hydrographic sheets shall be 36 by 54 inches and they shall ordinarily not exceed this size (see 1–8 and 6–3). Chiefs of Party are authorized to increase the sheet size to 36 by 60 inches in exceptional cases, but approval must be obtained from the Director before using a sheet larger than 36 by 60 inches. Flat sheets 36 by 60 or 42 by 60 inches will be furnished on requisition to the Washington Office and shall be used for boat sheets and smooth sheets. Use of other types of paper for this purpose is not authorized. The 42-inch width may be used when considerations of control make it advisable; however, hydrography should be limited to an area 30 inches wide in order that the sheet may be trimmed after verification and review.

Calibration sheets should be constructed on aluminum-mounted paper or on mylar. The aluminum-mounted paper best satisfies the distortion problem but sheet size is restricted to 24 by 31 inches. The paper must be mounted on both sides of the aluminum; a single mounting will warp the sheet. Grained mylar is available in sizes up to 36 by 60 inches.

Unless otherwise instructed, all planetable topographic or graphic control surveys shall

be done on aluminum-mounted sheets. The size used is 24 by 31 inches, which is identical with the size of the planetable board.

2–23 Subplans.—Sheets containing small detached areas of hydrography shall be avoided, if practicable. This can usually be accomplished by placing a subplan, or inset, on the boat and smooth sheets at the same or an enlarged scale (see 6–6). If it is impracticable to include, in the original sheet layout, an entire area on several standard-sized sheets, and a small section remains that is necessary for effecting a junction with a prior survey, it is frequently practicable to include such area as a subplan on an unused portion of the adjacent sheet. Such subplans must always be included on the sheet of comparable scale closest to the area.

Where a small harbor, anchorage, or other area needs to be surveyed at a larger scale than the remainder of the inshore coastal waters, it likewise may frequently be included as a subplan on the sheet which includes the area.

It is to be noted that the boat sheets are not necessarily similar in layout to the smooth sheets and there is no objection, and in many cases there is a decided advantage, in surveying the area on separate boat sheets. The results of several small boat sheets may be included on one smooth sheet.

2–24 Dog-ears.—It is sometimes impracticable to determine in advance the exact limits of a hydrographic sheet. Because of developments during progress of a survey or the location of control, it is occasionally desirable or necessary to use a control station which falls a short distance beyond the limits of the sheet as originally laid out. This is accomplished by adding a small section of paper, called a "dog-ear," to the boat sheet and plotting the station thereon. While there is no objection to the use of dog-ears on boat sheets, there is serious objection to their use on smooth sheets, and they are not to be tolerated on the latter except in emergency (see 6–5).

2–25 Shore party operations.—It is frequently more efficient to assign a portion of the work, especially triangulation and topography, to one or more shore parties operating independently but responsible to the Chief of Party. In well-developed areas these parties can generally use trucks for transportation during progress of the work and for changing base of operations. Photogrammetrists are usually assigned to assist hydrographic parties in the United States, and are self-sufficient. The party will usually have an office-trailer, one or two trucks, and a small boat which can be launched from a trailer when needed.

Where launch hydrographic surveys, or other operations requiring the use of boats, are made by a party based ashore, the camp sites or anchorages must be chosen so that time required for runs to and from the working ground will be at a minimum, and at the same time provide safe anchorage for the floating equipment.

When electronic distance measuring equipment is used to control hydrography, it will be necessary to establish a small unit at each shore station. Since all shore-based units must be supplied at regular intervals, the locations selected should be such that landings can be made under all conditions of sea and weather, if possible.

2–26 Radio communications with detached units.—Most launches, and shore parties operating from a ship, will be equipped with radiophones and will be in communication with the Chief of Party at regular intervals. The Radio Regulations of the International Telecommunications Conference are very specific with respect to procedures to be employed when radiophones are used. The Chief Electronics Technician, or other responsible person on each party, shall train all users of radio communications equipment in order that infractions of the regulations will be avoided. Copies of the regulations are furnished without request as they are issued.

2–27 Weather.—Few operations in a hydrographic survey can be conducted with efficiency and accuracy during periods of stormy weather and much of the work re-

FIGURE 17.—Raydist Red and Green shore station equipment.

frequency. Whip antennas may be used as in 3–52, or the antennas may be duplexed.

3–54 **Power sources.**—Electric power for operation of ground stations, approximatly 3 kilowatts, may be obtained from commercial sources, 115–120 volt—60 cps, or from portable generators at the stations. If commercial sources are used, it is advisable to have a portable generator at each station ready for emergency use in event of a power failure.

3–55 **Range and accuracy of Raydist.**—The maximum range at which the D.M. Raydist can be used satisfactorily for control of hydrography has not been determined through experience. Strong signals from the Green station have been received at a distance of 225 nautical miles. At the same time signals from the Red station, which was 175 miles distant, were not usable. In this instance the antennas at the Red station were duplexed and signals were not as strong as they were with the three-tower system.

Raydist signals are subject to interference by skywaves at night if the strength of the skywave signal is greater than that of the groundwave. Skywave contamination may be expected at distances greater than 100 miles. This applies to the distance between ground stations as well as the distance of the mobile station from either ground station. Atmospheric conditions will also affect Raydist. Electrical storms near any station or between stations and rain static at any station will frequently affect the lane count. Strong radio communication signals close to a frequency used in the system may interfere with its operation, especially if some skywave contamination is present.

Interference with Raydist signals has the effect of causing the phasemeter dials to show a gain or loss of lanes. These will also show on the brush recorder tape. By keeping a close watch on the tape it is possible to detect the gains or losses. The observed values can be corrected accordingly. Gains or losses will be in whole lanes, not fractions of a lane. Skywave interference will cause the phasemeter dials to oscillate through an arc which increases with the strength of the wave. A continuous strong skywave signal will cause such erratic operation that it will be impossible to keep track of the lane count and the sounding line must be broken.

Raydist distance measurements are accurate to a few tenths of a lane and accuracy does not deteriorate with distance so long as usable signals can be received. Errors in distance measurements remain constant at any distance except as noted in 3–56. The system does not provide a method of lane

identification. If the lane count is lost it is necessary to return to a known point and reset the counters before continuing hydrography.

3–56 Corrections to Raydist measurements.—As stated in 3–50 the R_2 lane width is assumed to be the same as that of the R_1 lane for drawing distance arcs from the ground stations. The R_2 distance and the width of the R_2 lane are complicated by the fact that an elliptical method is used to measure the sum of the R_1 and R_2 distances and then the R_1 distance is subtracted in the phasemeter. The correction is a function of the cycle differences in two signals, usually 400 cps.

For example, if a frequency of 3280 KC is used at the mobile transmitter, a frequency of 1639.8 KC will be used at the Red station distance measuring (C–W) transmitter. The R_1 lane width will be 149.87307 feet, which is obtained by dividing 983,167,-315 feet by 3280 and then dividing the resulting wave length by 2. In this instance the

R_2 distance in feet$=149.87307\psi_G+0.00012(R_1-R_2)$ in which

ψ_G=Phasemeter reading for the R_2 station in lanes.

R_1=Distance to Red station in feet.

R_2=Distance to Green station in feet.

The R_2 distance in the sum of the R_1 and R_2 distances is measured directly, but by an effective frequency of 3280.400 KC which is 400 cycles larger than the frequency used to compute the lane width. The 3280 KC frequency from the mobile transmitter is returned to the ship on a frequency of 3280.400 KC. The factor 0.00012 is the quotient when 400 is divided by 3,280,000.

The above formula is difficult to use in the field but it can be reduced to a formula by which a correction to R_2 distances can be computed when the mobile station moves from the point where the dials are set. The correction formula is:

R_2 correction (in lanes) $= +0.00012[(\psi_R'' - \psi_R') - (\psi_G'' - \psi_G')]$ wherein the subscripts R and G indicate R_1 (Red) and R_2 (Green) phasemeter dial readings respectively and $''$ and $'$ indicate readings at the calibration point and the point for which correction is desired, respectively. The formula is used with the R_2 lane width the same as that of the R_1 lane and no correction is applied when the R_2 dial is set at the calibration point.

A second correction to R_2 distances is required if three antennas are used at the Red station. If antennas are duplexed at the Red station this correction is eliminated. The arrangement of the three-antenna system is described in 3–52. The correction to R_2 distances is related to the location of the C–W (distance measuring) transmitter with respect to the center of the antenna system at the Red station. The correction is expressed in the formula:

Correction to R_2 distance (in lanes)$=d$ cosine $(A_s - A_t)$ in which d is the distance in lanes from the Red station center to the C–W transmitter antenna, A_s is the azimuth of the mobile unit from the Red station center, and A_t is the azimuth of the C–W transmitter antenna from the Red station center (Fig. 18).

The point of origin for measurement of distances on a ship using three antennas is related to antenna locations and may be some distance from the location of the echo sounder transducers, which, on most ships, are located within a few frames of the foremast. With the distance-measuring signal antenna at the main mast and the receiving antennas at the foremast, the point of origin for the R_1 distance is midway between the masts (Fig. 19) The origin of the R_2 distance cannot be defined as a single point because of the elliptical configuration, but for this computation is assumed to be at the main mast. The R_1 and R_2 distances may be reduced to the foremast by applying a lane correction derived from the formulas:

$$C_1=\tfrac{1}{2}D \text{ cosine } (SH-Ar)$$
$$C_2=\tfrac{1}{2}D \text{ cosine } (SH-Ar) - D \text{ cosine } (SH-Ag)$$

Where

C_1=correction to R_1 distances in lanes

C_2=correction to R_2 distances in lanes

255 cannot be switched from feet to fathoms operation as has been the custom with the 808 fathometer. When it becomes necessary to change modes, the stylus drive motor must be repositioned and the fathoms calibration switch placed in the ON position. The change shall be made by a qualified technician, and unskilled personnel are not authorized to attempt it. The hydrographer should plan his work so that changes, if required, shall be kept to a minimum.

3–88 **Operating manual.**—A technical manual is furnished with each EDO–255 recorder and contains complete instructions for servicing and adjusting the instrument. Personnel assigned to operate the recorders should be instructed in procedures for changing paper rolls and stylus needles as well as normal operating procedures. All other servicing or repair shall be done by electronic technicians. A record of servicing and repairs should be kept for each instrument, and should accompany it if transferred to another survey vessel or party.

3–89 **808 Fathometer.**—The 808 Fathometer (Fig. 27) is a semiportable, supersonic, graphic-recording, echo-sounding instrument designed for hydrographic surveying in shallow to moderately deep water from vessels of all sizes. Its range is from about 2 feet below the transducer to 160 fathoms. The 808 Fathometer has been the standard shoal water sounder since 1939. The sounder records on a graph through a stylus operating in a circular sweep. The range of scale of the record paper is 55 divisions, and by means of a phasing arrangement with a 20-unit overlap, three other ranges may be recorded thus providing for an expanded scale covering a range of 0 to 160 units, either feet or fathoms.

A contract has been awarded to reengineer the 808 Fathometer to incorporate several new features which will improve its capabilities and correct some of the operating deficiencies of the old models. The specifications are not fixed, and a detailed description is not available.

3–90 **Operating characteristics of 808 Fathometer.**—The fathogram paper used on 808 depth recorders is designed for the following conditions of operation:

Calibrated for velocity of sound.	820 fm/sec . .	800 fm/sec.
Center reed of tachometer.	67.1 cps . . .	65.5 cps.
Motor armature speed	4,026 rpm . .	3,928 rpm.
Stylus arm speed, feet	671 rpm . . .	654.6 rpm.
Stylus arm speed, fathoms.	111.833 rpm .	109.104 rpm.
Time per revolution, fathom scale.	0.5365 sec . .	0.5499 sec.
Effective length of the stylus arm (4.419 inches).	11.224 cm . .	11.224 cm.
Chart paper speed, foot scale.	2 in/min . . .	1.95 in/min.
Chart paper required .	15, 15UE or ES–9.	TCI–3008.

3–91 **Motor speed.**—The accuracy of the recorded depth is directly related to the motor speed, and the motor must always rotate at calibration speed. The motor speed is controlled by means of a centrifugal type governor attached to one end of the motor frame. A Frahm vibrating-reed type of tachometer provides a visual monitor of the motor speed. The tachometer is composed of seven reeds; the middle reed, vibrating at maximum amplitude, indicates correct motor speed for the calibrated velocity of sound in seawater. Tachometers may be constructed for any desired velocity, but only two are used: 800 or 820 fathoms per second. The fathometer operator must be constantly alert and adjust the motor speed when necessary to keep the middle reed vibrating at maximum amplitude (see 5–55). The fact that the motor speed is correct should be recorded at frequent intervals. Variations in motor speed are indicated by the tachometer and the paper speed, but the paper speed is not always a true measure of the motor speed and care shall be taken that paper slippage is not misinterpreted as incorrect motor speed. Daily checks should be made on paper and speed and rpm count against a stop watch, and recorded (see 5–110 and 111).

3–92 **Stylus arm length.**—Accuracy of recorded depth also depends on the rate of travel of the stylus over the fathogram, and the radial distance to the stylus contact must be 11.224 cm (4.419 inches). An abnormal

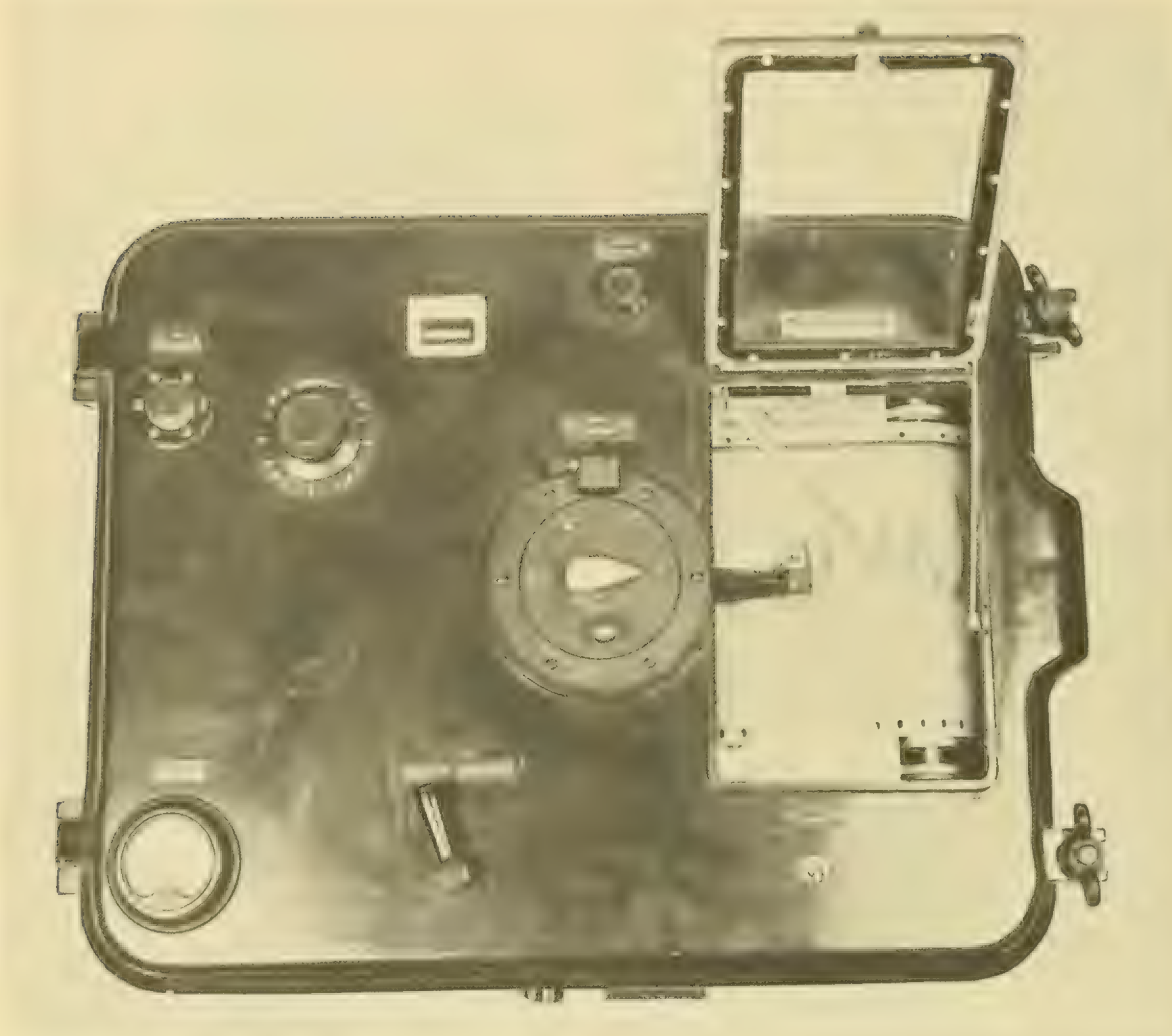

FIGURE 27.—808 type shoal water echo sounder.

length of stylus arm is indicated when the stylus and printed arcs do not coincide, the center of rotation being correct. The length can be checked by comparing the stylus arc with arcs of various radii drawn on a plastic sheet. The effective length should be correct within 0.040 cm (0.010 inch). The effective length varies with projections of the spring stylus. Adjustment is provided in the stylus holder trunion screws. The screws should be locked, or sealed, to prevent movement, by the lock screws in the back of the metal frame holding the stylus. If the screw adjustment is insufficient, the bakelite insulator can be shimmed or filed.

3–93 **Alignment of fathometer paper.**— Since the 808 echo sounder is designed to record soundings with a circular sweep, the fathogram paper must be correctly positioned with respect to the radius of rotation of the stylus arm. The paper alignment is correct when the paper is moving across the platen so that the extended centerline of the paper will pass through the center of rotation of the stylus arm and the paper moves in a direction parallel with the lines on the paper. The operator should occasionally check the paper alignment by causing a fix mark to follow one of the printed arcs on the chart. If the fix mark follows the arc

for deep casts, alternating current electric drive cannot be used unless complex and expensive control systems are incorporated.

An advanced type of oceanographic winch (Fig. 30) specially designed for the purpose is coming into use. The winch has electro-hydraulic drive powered by a 15 HP constant speed electric motor driving a piston-type hydraulic pump. Control is exercised by stroking the pump, i.e., varying the length of stroke of the piston. The equipment is capable of a line pull of 1,500 pounds at 300 feet per minute. The capacity of the winch drum is 30,000 feet of $\frac{5}{32}$-inch stainless steel cable. The new winch is substantially superior to the older types in that it provides greater line pull, increased retrieving speed, improved control, more protection of equipment afforded by the hydraulic system, and several safety features. The most important safety feature is the automatic overhauling device which operates as follows: when the line pull exceeds 1,500 pounds, the hydraulic fluid is vented to a by-pass and the winch overhauls at a slow speed until stopped by the brake. This prevents closer approach to the 2,200 pound breaking strength of the cable and possible loss of an expensive group of instruments or the cable which is also costly.

This is an intermediate size winch suitable for lowering small corers, cameras, Nan-

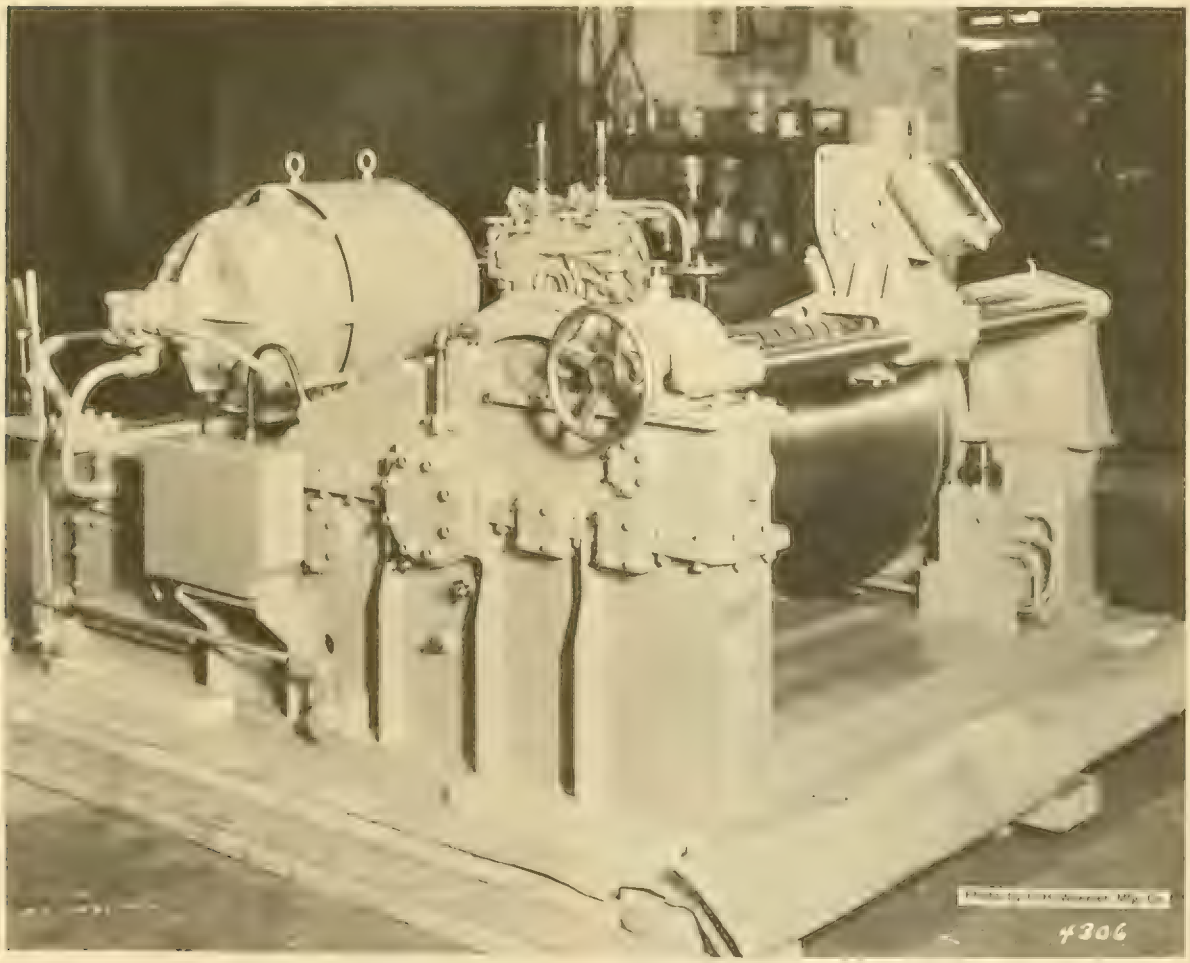

FIGURE 30.—A modern electro-hydraulic oceanographic winch with a capacity of 30,000 feet of 5/32 inch wire rope.

sen bottles, and instruments of similar size and weight. Heavy duty winches now under development will be capable of storing upwards of 40,000 feet of tapered cable (3/8 to 3/4 inch) and exerting a line pull of 30,000 pounds at 130 feet per minute. Traction devices separate from the storage drums are required. The winch will be used for obtaining large cores, deep dredging, or for anchoring in great depths.

The oceanographic winch is mounted on deck so that the cable can be lead directly outboard to an "A" frame or boom. When bottom samples, dredge hauls, or underwater photographs are taken, a dynamometer, ball breaker, or sonar pinger should be used to indicate when bottom has been reached.

3–112 Bathythermograph winch.—The BT winches now in service are powered by 3 HP single speed electric motors. This power is inadequate to utilize the full working strength of the 3/32-inch cable. The winch is being redesigned to incorporate electro-hydraulic drive powered by a 5 HP motor (Fig. 31). This will provide greater flexibility in the use of this equipment and it should be suitable as an all-purpose oceanographic winch for small survey vessels.

The winch is designed primarily for use in lowering a BT both while underway and when drifting or anchored on station. The reel will hold approximately 3,000 feet of 3/32-inch 7 × 7 stainless steel aircraft cord which has a breaking strength of 1,500 pounds. The winch may be used for a variety of purposes in appropriate depths; such as: Nansen bottle casts, bottom sampling with small samplers, lowering cameras or plankton nets, and as a sounding machine.

FIGURE 31.—Bathythermograph winch.

3–113 Dredging winch.—Any available winch may be modified to serve as a dredging winch in moderate depths of 200 to 400 fathoms. The winch should have a storage capacity of 900 fathoms of 3/8-inch cable or 500 fathoms of 1/2-inch cable and a level wind device to lay the turns evenly on the drum. A power supply sufficient to exert a pull of about 5,000 pounds is required. There should be an indicator to show the amount of cable paid out.

Two methods have been used on C&GS ships to provide a dredging winch which meets the above requirements. The wire rope drum on the anchor windlass may be adapted for the purpose, or a boat hoisting winch may be used. See Section 3–131 for a description of dredges.

3–114 Bourdon type bathythermograph (BT).—The bathythermograph (Fig. 32) consists essentially of a thermal element and a pressure or depth element so constructed that a staballoy coated glass slide driven by the pressure element moves at right angles to a stylus which in turn is driven by the thermal element. A trace showing temperature with relation to depth is drawn on the slide as the BT is lowered and raised.

The BT may be lowered while underway or when lying to on station. BT's are furnished for three ranges: 200 feet, 450 feet, and 900 feet. A BT should never be lowered deeper than its designed range. BT slides shall be marked in accordance with instructions contained in the manual furnished with each BT.

A special grid is supplied for each instrument for converting the stylus trace to temperature and depth readings. These grids

FIGURE 32.—Bourdon type bathythermograph.

are not interchangeable between instruments, since each grid is calibrated for a particular BT. Never let the temperature of the BT exceed 105° F. At this temperature the stylus brings up against a stop pin; if this temperature is exceeded, permanent deformation of the brass coil in the Bourdon will occur and the calibration of the instrument will be ruined.

In addition to the manual furnished with each BT, observers should study Sections 2–32 to 2–59, inclusive, of H.O. Pub. No. 607, Instruction Manual for Oceanographic Observations.

3–115 Reading BT slides in the field.—When required by project instructions, the BT slides shall be scanned in the field and the data recorded on Form 732, Field Record of BT Data (Fig. 33), as follows:

Insert the slide in the proper grid. Record the slide number, date and time of observation, surface temperature as observed with the bucket thermometer, and the distance in feet that the BT trace terminates above (a) or below (b) the zero depth line on the viewing grid. Record the surface temperature (temperature at the top of the trace) as shown by the BT. In the first column at the left of the form enter, from top to bottom, decreasing temperature values at one-degree intervals to cover the range of temperature to be recorded from that slide. With the BT slide firmly in place in the viewing grid, read and record in the second column the depth at which each degree of temperature is encountered. No corrections shall be made. At the bottom of each column record the temperature and depth of water at the lower end of the trace. If a temperature inversion is observed, use extra columns as may be needed and as shown in the illustration.

At end of season or project, BT slides, BT log sheets, and Forms 732 shall be forwarded to the Washington Office in separate mails.

3–116 Temperature and salinity observations.—Nearly all hydrographic parties are required to measure the temperature and salinity of sea water either as part of a program of oceanographic observations or to obtain data for determining the velocity of sound. In the latter case, the data are required to correct echo soundings when the calibrated velocity of the sounder differs from the actual velocity (see 5–114). The program of observation involves measurements from the surface to the bottom at intervals which will permit drawing accurate temperature and salinity curves.

The International Association of Physical Oceanography, in 1936, proposed the following standard depths at which observations

FORM 732 (2-11-59) FIELD RECORD OF BT DATA																	
U.S. DEPARTMENT OF COMMERCE COAST AND GEODETIC SURVEY																	
YEAR	1958																
VESSEL	Ship HYDROGRAPHER																
CHIEF OF PARTY	G.R. Fish																
GENERAL LOCATION	South of Georges Bank																
(TEMPERATURE IN °F DEPTH IN FT.)																	
SLIDE NO.	2	3	4	5	5	5	5	6	6	6	6						
DATE	8/8	8/8	8/8	8/8				8/9									
TIME	2100	2200	2300	2400				0100									
SRF. TEMP. (BUCKET)	64.8	61.2	63.5	67.0				68.4									
SRF. TEMP. (BT)	64.5	61.0	63.2	66.8				68.0									
*TRACE FT. a OR b	1a	0	1b	2b				1b									
TEMP	DEPTH							Temp	Depth								
65				30 36				68	Surf.								
64	15			38				67	40								
63	22		5	44				66	43								
62	30		20	60				65	50								
61	35		24	78				64	57								
60	37	30	25	80				63	60								
59	38	32	28	80				62	65								
58	40	37	29	80				61	72								
57	44	40	30	100				60	77								
56	48	47	35	108				59	78								
55	50	53	39	108				58	79								
54	52	61	42	110				57	80								
53	55	70	43	112				56	81								
52	60	81	46	114				55	90	280	300						
51	70	110	48	116			440	54	98	270	360						
50	72	140	50	118			420	53	99	268	420						
49	77	180	60	120			410	52	118	265	540						
48	90		70	135	170	270	380	51	125	257	590						
47	130		110	150	240	340		50	142	252	630						
46	152		250	160				49	165	245	680						
								48	175	235							
								47	185 220	230							
BOTTOM TEMP (BT)	45.8	49.0	46.0				50.5				49.0						
BOTTOM DEPTH (BT)	170	190	270				490				690						

*INDICATE NUMBER OF FEET BT TRACE TERMINATES ABOVE (a) OR BELOW (b) SURFACE LINE ON VIEWING GRID.

USCOMM-DC 27305-P

FIGURE 33.—Sample field record of bathythermograph data, Form 732.

should be taken directly or the data adjusted by interpolation from the distribution at other levels. The standard depths, in meters, are: 0, 10, 20, 30, 50, 75, 100, 150, 200, (250), 300, 400, 500, 600, (700), 800, 1000, 1200, 1500, 2000, 2500, 3000, 4000, and thence at 1000 meter intervals to the bottom. The depths in parenthesis are optional. Refer to H.O. Pub. 607 for detailed instructions covering observation procedures.

Several factors influence the spacing of sample bottle depths, particularly in the upper layers, in turbulent water, and in areas of upwelling or where temperature inversions occur. It is desirable to determine the temperature curve accurately from surface to bottom. A BT lowering to maximum depth should be made at each oceanographic station. The BT trace will show temperature gradients, disclose the existence of inversions, and assist in selection of appropriate depths for sampling. Steep gradients may require closer spacing of the bottles.

Because oceanographic data are assembled from many sources on a nation-wide basis and processed by machines, it is desirable to use the International Standard Depths. When serial temperatures and salinities are observed for correction of soundings in relatively small project areas and the registering sheave is graduated in fathoms, observations should be taken at the following approximate depths: 0, 2, 5, 11, 16, 27, 41, 55, 82, and 109 fathoms.

3–117 Protected reversing thermometers. —Two types of protected reversing thermometers are used by the Coast and Geodetic Survey. One has a scale graduated to 0.2 degree C. and without an enclosed auxiliary thermometer. It is used in a Tanner-Sigsbee Reversing Frame. The second type is somewhat larger, is graduated to 0.1 degree C., is accurate to a few hundredth of a degree, and has an auxiliary thermometer enclosed (Fig. 34). This is a more precise thermometer and should always be used in Nansen Bottle casts at oceanographic stations. Requisitions for protected reversing thermometers should state the type desired—that is,

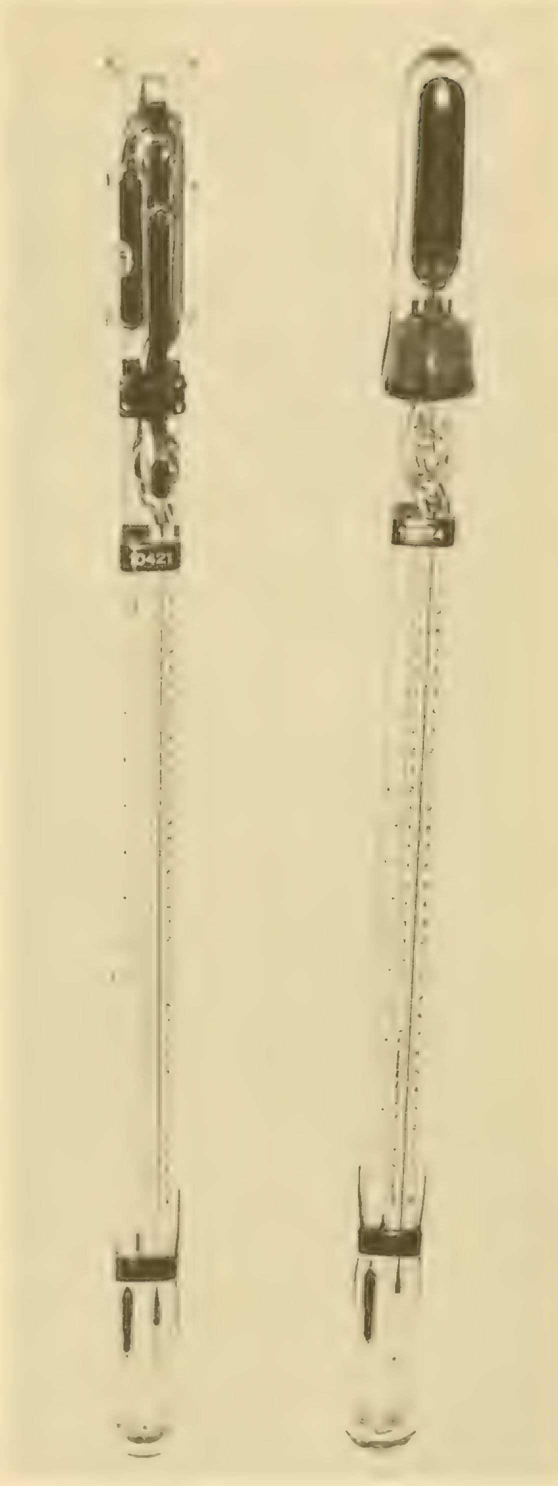

FIGURE 34.—Precision type deep sea reversing thermometers, unprotected on left, protected on right.

for use in Nansen bottles, or Tanner-Sigsbee reversing frames.

Reversing thermometers are delicate instruments and must be handled with extreme care at all times. A protected thermometer is enclosed in a heavy glass case sealed at both ends to protect it from pressure of the water. The special features of a reversing themometer are: a knife-edge in the capillary tube which is made by an appendage in the tube; a gooseneck which may take the form of a U-turn, S-turn, or a complete circle, and a supplementary mercury reservoir at the opposite end from the main reservoir.

When the thermometer is reversed, or inverted, the extra weight of the mercury in the enlarged section of the capillary tube in the gooseneck breaks the mercury column at the knife-edge, the mercury flows into the supplementary reservoir, and extends into the graduated stem where the temperature is read when held in an inverted position. Thus, when the thermometer is reversed in water at any depth, the temperature at the point of reversal is obtained. Since the jacket protects the thermometer from hydrostatic pressure a true reading of temperature can be made. If the thermometer does not have an auxiliary, the temperature should be read as soon as possible after it is brought to the surface.

3–118 Unprotected reversing thermometers.—An unprotected reversing thermometer is similar to the protected type in most respects except that one end of the glass jacket is open. The thermometer is in direct contact with the water and is subject to hydrostatic pressure. It has no mercury surrounding the reservoir as does the protected thermometer. It does not give a true temperature reading but gives a reading which increases in direct relation to the depth. By pairing a protected and an unprotected thermometer on one Nansen bottle the temperatures can be used to determine the depth at which the thermometers were reversed.

3–119 Care of thermometers.—Deep-sea reversing thermometers are expensive instruments. Each one must be carefully calibrated at considerable additional expense. Unless they are properly handled the mercury column may be separated by gas bubbles in the capillary and the calibration lost. The following rules should always be observed when using these instruments:

(a) Avoid laying a reversing thermometer in a horizontal position.

(b) When not in use, each thermometer should be placed in its individual cylindrical case and stored in a padded carrying case with the large mercury reservoir down. Always keep the carrying case in an upright position.

(c) All thermometers should be washed in fresh water and dried before storing them in the case.

(d) Handle them gently, if the mercury fails to return from the supplementary reservoir a light tap with the finger will bring it down.

(e) Never store the thermometers in the Nansen bottle frames. If the thermometers are left in the Nansen bottle frames during a run between stations, the bottles should be placed in the storage rack with the large mercury reservoirs down.

3–120 Corrections to observed temperatures.—A calibration certificate is furnished with each reversing thermometer from which graphs can be drawn and corrections scaled as needed. Precisely measured temperatures are not required for computing corrections to echo soundings, however, observed temperatures should be corrected from the calibration graph and the final results should be accurate to one or two tenths of a degree. Observed temperatures may contain small errors from two different sources. One of these is an intrinsic error of the thermometer due to slight irregularities in the capillary tube and slight errors of graduation. Corrections for these errors are determined by calibration. The calibration curve retains its shape but moves slightly with respect to the freeze point and with age until the glass becomes stable.

The other error is due to the change in the volume of mercury contained in the

which cannot be taken by other types of samplers.

Dredges are of various designs. A section of 10- or 12-inch steel pipe about 3 feet in length can be used. One end of the sampler is closed by welding steel bars across it so as to retain large specimens. Wire mesh screens of various size openings may be used in the bottom of the dredge to retain samples of any desired minimum size and the finer sediments will be washed out.

Another type of dredge is constructed of ¼-inch steel plate, and is 1 foot deep, 2 feet wide, and 3 feet long. The bottom is closed and screened as above.

A third type is constructed of a rectangular steel collar to which is attached a purse of chain mail (Fig. 42). Interior of the purse may be lined with screens as in the other dredges or with netting, shrimp net being commonly used.

If specimens of the sediment or other fine particles are desired, a small section of 2-inch pipe with a canvas bag at one end may be towed behind the dredge.

FIGURE 42.—Chain mesh dredge.

It is advisable to rig the dredge with a short section of chain above the bridle which is hooked to a weak link. Another cable shackled above the weak link leads to the after end of the dredge. If the dredge fouls on fast rock, the weak link will break, the second cable will dump the dredge and clear it from the bottom.

The samples should be transferred to water-tight containers, labeled and stored or shipped in accordance with instructions.

3–132 Other oceanographic instruments.—In recent years, oceanographic and electronic laboratories have developed new types of instruments for measuring chemical and physical properties. Some of these instruments are capable of measurements *in situ* while others are restricted to laboratory use. New designs in camera equipment permit the taking of a series of stereophotographs at one lowering to the ocean floor. Most of the *in situ* instruments supply information to dials or recorders aboard the ship or require a shipboard source of power; this frequently requires multiconductor cables whose lengths generally govern the maximum depths to which the instruments can be used. Many of the laboratory instruments, because of their precision, require power supplies with very narrow ranges in voltage and frequency. A few of the instruments are described briefly in the following paragraphs.

3–133 Induction Conductivity Temperature Indicator (ICTI).—The ICTI was developed by the Chesapeake Bay Institute for use in oceanographic studies in estuaries and other shoal water areas along the Atlantic Coast. The instrument measures conductivity and temperature *in situ* and salinities can be computed from these data. The ICTI consists of shipboard indicators, an underwater unit for measuring conductivity, a resistance thermometer, and a connecting cable (Fig. 43).

In the conductivity unit, there are two coaxially mounted iron-cored inductors which are insulated from the water. The first cores winding is connected to 115 V 60 cps, so that a low voltage will be induced in any one turn link which threads the hole in this core. The total current flowing through the hole is proportional to the conductivity of the

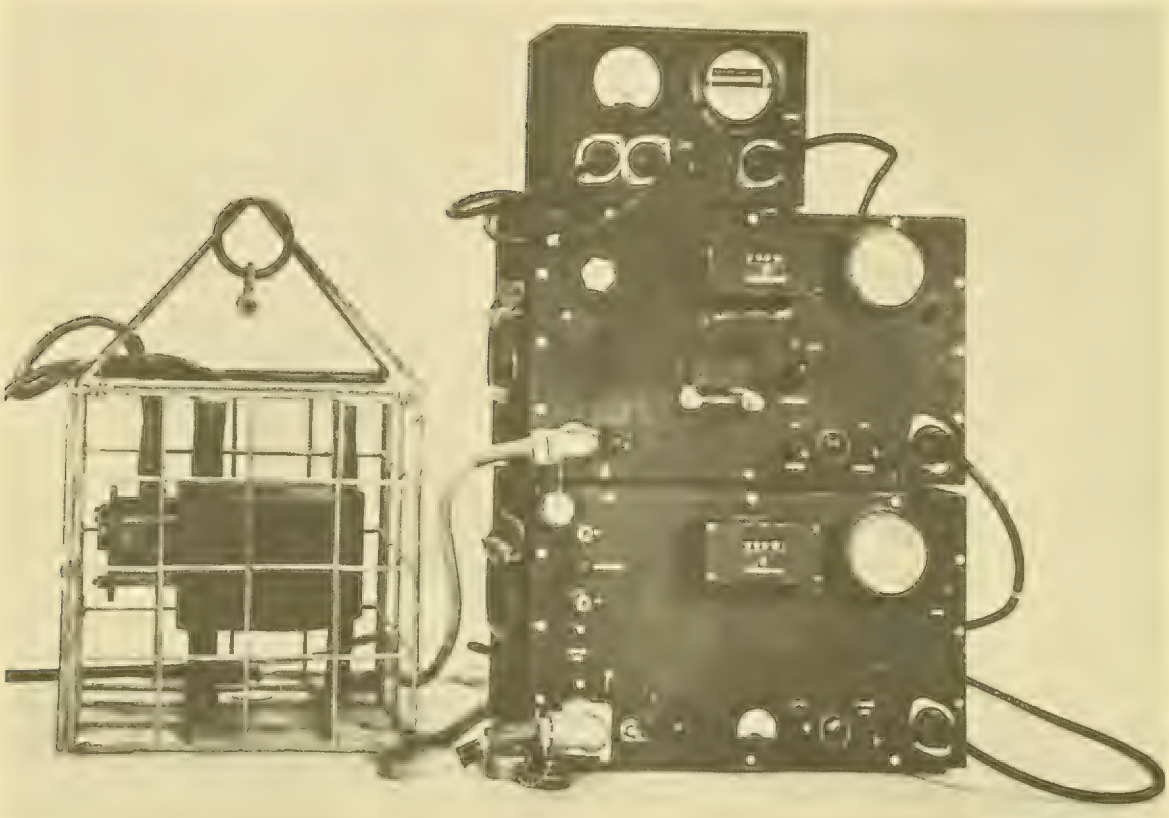

FIGURE 43.—Chesapeake Bay Institute ICTI.

water in which the transformer is immersed. This current is measured by the second core, and the output signal is transmitted, along with a reference voltage derived from a secondary winding on the first core, through the cable to the indicator aboard ship, where the information is automatically processed and actuates a counter so that conductivity is read directly. The conductivity reading and the simultaneously observed temperature are used to enter tables from which salinities are extracted.

The temperature sensing element is a resistance thermometer, made from about 25 feet of enameled nickel wire wound around a tube and connected to the cable. The temperature measuring circuit is a modified Wheatstone bridge. Temperature is shown directly on a dial to 0.01° C.

3–134 Salinometer (salinity bridge).— The Salinometer, or salinity bridge (Fig. 44) is an instrument for the determination of salinity of sea water aboard ship or in the laboratory by an electrical conductivity method. The first apparatus of this kind was constructed by the National Bureau of Standards in 1930 and is known as the Wenner-Smith-Soule Salinity Bridge. Several improvements have been made in the equipment, the most recent being described in Technical Report No. 61 published by the University of Washington in 1958.

The equipment consists of the bridge-oscillator detector unit, a refrigerated oil-tight constant-temperature bath, seven conductivity cells mounted in the bath, a refrigerator unit and controls, a proportional-type temperature controller, a constant-voltage supply for the electronic parts, and a suction system for emptying the cells.

The salinometer is calibrated in the laboratory by a lengthy series of measurements of

development of echo sounding equipment are considered inadequate for modern charting purposes. Some areas are subject to change by storms, tidal currents, or engineering developments and must be resurveyed periodically. These are revision surveys and instructions may require a complete basic survey of the area, or limited surveys in areas of danger (see 5–125 and 127).

5–3 **Survey operations.**—Instructions for a survey project (see 2–5 to 13) will be issued and the necessary data furnished sufficiently in advance of field work to permit formulation of a general plan of operation (see 2–15). Plans for day to day operations must be fitted into the general plan as circumstances dictate in order that operations can be carried on smoothly and efficiently. All survey operations required in an area should be completed as the work progresses. Miscellaneous operations such as magnetic observations, development of shoal indications, compilation of coast Pilot notes, etc., should be kept up to date.

A hydrographic survey has not served its ultimate purpose until it has been incorporated in a published nautical chart. The data accumulated should be processed as rapidly as possible. Periods of inclement weather should be devoted to processing, and, when a considerable volume of unprocessed records have been accumulated, it is advisable to use periods of marginal weather for this purpose (see 5–100 to 123 and Chapter 6).

5–4 **The boat sheet.**—The boat sheet is the hydrographer's work sheet used in the field to plot the details of a survey while it is in progress. On it is laid out a proposed plan of sounding lines spaced in accordance with instructions. Fixed position are plotted as they are observed. Soundings, reduced for tide or other significant corrections, are inked on the sheet and depth curves drawn. Daily examination of the results will disclose indications of shoals which must be examined and where additional lines are required to comply with project instructions or to define depth curves more adequately.

The boat sheet is similar to the smooth sheet (see Chapter 6) but may be less accurate and generally not so neatly done, but all information plotted on it should be as accurate as circumstances permit and clearly legible. No important information should be omitted. Temporary or permanent notes may be written in margins or on land areas.

A photographic copy of the boat sheet will be used to apply corrections, if necessary, to the chart of the area. The boat sheet will be used by the smooth plotter and will be referred to many times as the smooth sheet is verified and reviewed.

5–5 **Boat-smooth sheet.**—When surveys are being made in offshore areas and electronic control is used, the boat-smooth sheet method of plotting the hydrography can be used to advantage, especially where very little development is required. When this method is used, the instructions for smooth plotting contained in Chapter 6 shall be followed with one exception: corrections to observed distances to the fixed stations shall be determined by careful calibration as described in Chapter 3, and the corrections applied on the abstract sheets as the positions are plotted. The records or descriptive report shall indicate any plottable differences between the final corrections and those used to plot the hydrography.

A transparent cover with matching projection ticks shall be placed over the smooth sheet while positions are being plotted. Tracing cloth or a thin sheet of grained mylar may be used for this purpose. As the positions are plotted they shall be pricked through the cover sheet to the smooth sheet. The cover sheet shall serve as a boat sheet and all position numbers and soundings shall be inked on it in the usual manner. At the end of the day or at other convenient times, the cover sheet is lifted and the positions on the smooth sheet connected by fine pencil lines. The position numbers are carefully inked in accordance with smooth sheet practices (see 1–10 and 6–45).

After all corrections have been applied the reduced soundings are plotted on the smooth sheet in pencil. Ordinarily the soundings are

not pencilled until the survey is complete, since movement of the cover sheet can produce undesirable graphite smears on the smooth sheet.

The boat-smooth sheet method of plotting a survey affords a real saving since only one projection is required and it is not necessary to plot positions a second time. The method is not restricted to use with electronic control systems. Chiefs of party should use this method of plotting whenever it is practicable.

5–6 Construction of boat sheet.—Boat sheets are constructed to cover specific areas as shown on the approved sheet layout (see 2–20). Boat sheet paper will be furnished by the Washington Office in flat sheets 36 by 60 inches or 42 by 60 inches (see 1–9).

The projections are constructed in accordance with instructions contained in Special Publication No. 5 (see 1–12). A layout sketch of the projection with distances in meters appropriate to the scale noted thereon should be made and checked before the projection is constructed. The layout may be retained for later use in constructing the smooth sheet projection. Although a boat sheet is subject to considerable distortion by rough use and exposure during progress of a survey, the projection should be accurately constructed and verified. See Table 1 for projection line intervals.

The projection should be constructed and checked the same day. The dms. and dps. of control stations should be plotted and checked as soon as possible. When electronic control is to be used, the distance circles should be drawn if the station locations are known (see 5–11). The projection is then inked in fine full lines about 0.15 mm wide.

Stamp No. 42, Hydrographic Survey (Fig. 50), shall be impressed in the lower right-hand corner and entries made in all applicable spaces. The initials of the persons plotting and verifying each item should be entered, together with the dates.

5–7 Projection template.—A template on Mylar, a very stable plastic, has been devised to facilitate construction of boat and smooth sheet projections. Nine points are marked on the template so that construction lines may be quickly and easily drawn. The construction procedure is as follows:

(a) Locate the center of the projection on the sheet. This is the intersection of the central meridian and parallel.

(b) Place the template on the sheet with the central point over the center of the projection and orient the template as required by the layout.

(c) Prick all nine points on the sheet and check the long diagonals to prove the perpendicularity of the construction lines.

(d) Draw pencil lines through the points in a north-south direction. The center line is the central meridian.

(e) Draw the central parallel construction line through the three points in the east-west direction.

(f) From line (e) set off the distances on lines (d) to the most northerly and southerly parallels and draw them.

(g) From the central meridian set off on lines (e) and (f) the extreme east and west meridians and draw them.

After the curvature values have been ap-

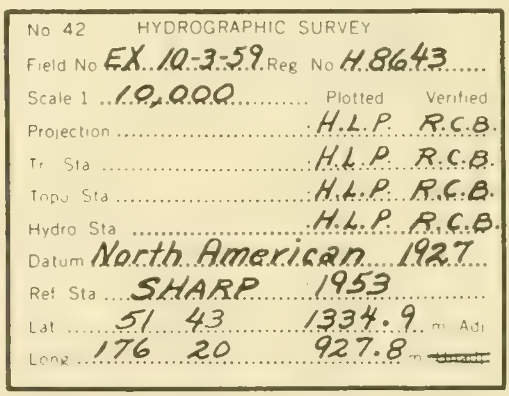
No 42 HYDROGRAPHIC SURVEY
Field No EX 10-3-59 Reg No H 8643
Scale 1 10,000 Plotted Verified
Projection H.L.P. R.C.B.
Tr. Sta H.L.P. R.C.B.
Topo Sta H.L.P. R.C.B.
Hydro Sta H.L.P. R.C.B.
Datum North American 1927
Ref Sta SHARP 1953
Lat 51 43 1334.9 m Adj
Long 176 20 927.8 m ~~Adj~~

FIGURE 50.—Facsimile of Stamp No. 42, projection and control data.

plied the four corners of the projection are located and the principle lines may be subdivided to draw the rest of the projection. Curvature values shall be included where necessary according to the scale of the projection.

5–8 Duplicate boat sheets.—When more than one survey unit is to work in the area covered by one boat sheet, a duplicate boat sheet can be made by pricking through the projection intersections with a fine needle. A long steel straight edge should be placed along each line as the points are pricked, being careful not to disturb the relation between the two sheets as the straight edge is moved.

Field numbers are assigned as in 1–13. The letter A should be added to the number on the original sheet and duplicates indicated by adding letters B, C, etc., to the field numbers.

When the area to be surveyed lies entirely within the limits of a photogrammetric manuscript, a boat sheet may be made by transferring the projection and shoreline from the blueline tracing of the manuscript. Joining two or more manuscripts for this purpose shall not be attempted.

5–9 Calibration sheets.—If a projection is required for calibration of an electronic-control system it shall be constructed on aluminum-mounted paper or on mylar. It is desirable that the scale of the projection be twice as large as the largest scale survey on which the system is to be used, and it must never be smaller than the largest scale survey sheet. The method of construction and plotting control are the same as for other projections, but the work must be very accurately done. The sheets are not numbered. They may be discarded after all data have been tabulated and verified.

5–10 Control stations.—All control stations, whose positions are known at the start of the survey, should be plotted on or transferred to the boat sheet and shall be shown by standard symbols (Fig. 79). The names of stations may be lettered on the boat sheet in freehand, provided they are unmistakably legible. They should not be placed in water areas or obliterate any essential detail on the boat sheet and must be placed so that they are clearly associated with the correct symbols (see 6–15). Existing names of control stations must be retained with their exact spelling. If a station is in the water area, such as a beacon or offlying rock, the name may be inked on land area nearby and an arrow or leader used to indicate the station to which the name refers. For each control station in the water area, notation should be made on the boat sheet as to whether the feature on which it is erected is permanent or temporary, and a short description should be added.

When control stations are numerous, as on an inshore hydrographic sheet, identification will be aided and confusion avoided if brief descriptions of the signals are noted on the boat sheet.

Each natural object used as a control station shall be described on the boat sheet. When it is conspicuous enough for use as a landmark, that fact should be included in the description.

As new control stations are located, they shall be plotted on the boat sheet by direct transfer or other accurate method. The plotting of all control stations should be verified before the station symbols are inked, and the fact noted on the boat sheet.

5–11 Electronic distance circles.—When an electronic system is to be used for the control of hydrography and the locations of the shore stations are known, arcs of distance circles should be drawn as soon as the projection has been verified. If the arcs must be drawn at a later date as the survey progresses, the projection should be checked for distortion and significant amounts equally distributed by procedures described in the following paragraphs.

When the shore stations fall on the sheet, the arcs can be drawn directly with a beam compass. Colored inks shall be used with a distinctive color assigned to each station. A circle of the same color about 5 mm in diameter, shall be drawn around the station

symbol. If an Edmonston Beam Holder is not available, a Horn center should be placed over the station mark to prevent damage to the sheet as the arcs are drawn. Radii for the circles should be measured along three lines drawn from the station. When boat-smooth sheet procedures are to be used, it is best to compute three points on the circle of largest radius and plot these points on the projection. If the measured distance does not check the plotted points the radius of each arc shall be multiplied by a factor which will distribute the distortion uniformly across the sheet.

The station may be off the limits of the sheet, in which case it is necessary to compute at least three points on three or four circles. When the area to be surveyed is not too far distant from the station, the outline of the boat sheet limits can be plotted on a nautical chart and three or four radial lines drawn from the station across the sheet as shown in Figure 51. The azimuth of the lines may be measured with a protractor and the distances scaled off the chart. Because of the distortion inherent in the Mercator projection, a Lambert conformal projection should be used when long distances are involved, especially if the scale of the survey is large. World Aeronautical Charts (WAC) at a scale of 1:1,000,000 are suitable for this purpose. An alternative method is to scale the coordinates of a point near the center of the sheet and compute an inverse between the point and the station. From the computed azimuth and distance a pattern of points on the circles can be developed and their coordinates computed. The scaled distances must be expressed in terms of the units measured by the system, that is: Microseconds for EPI, statute miles for Shoran, and lanes for Raydist. The distances are then converted to meters. Table 7 can be used to convert microseconds to meters and Table 8 to convert statute miles to meters. Since lane width for the Raydist system is a function of the frequency used and is expressed in meters, no conversion table is necessary.

The geographic coordinates of the points A1, B1, C1, etc., in Fig. 51, are computed and plotted on the sheet. The radial lines should pass through the computed points along each azimuth, and a circle should

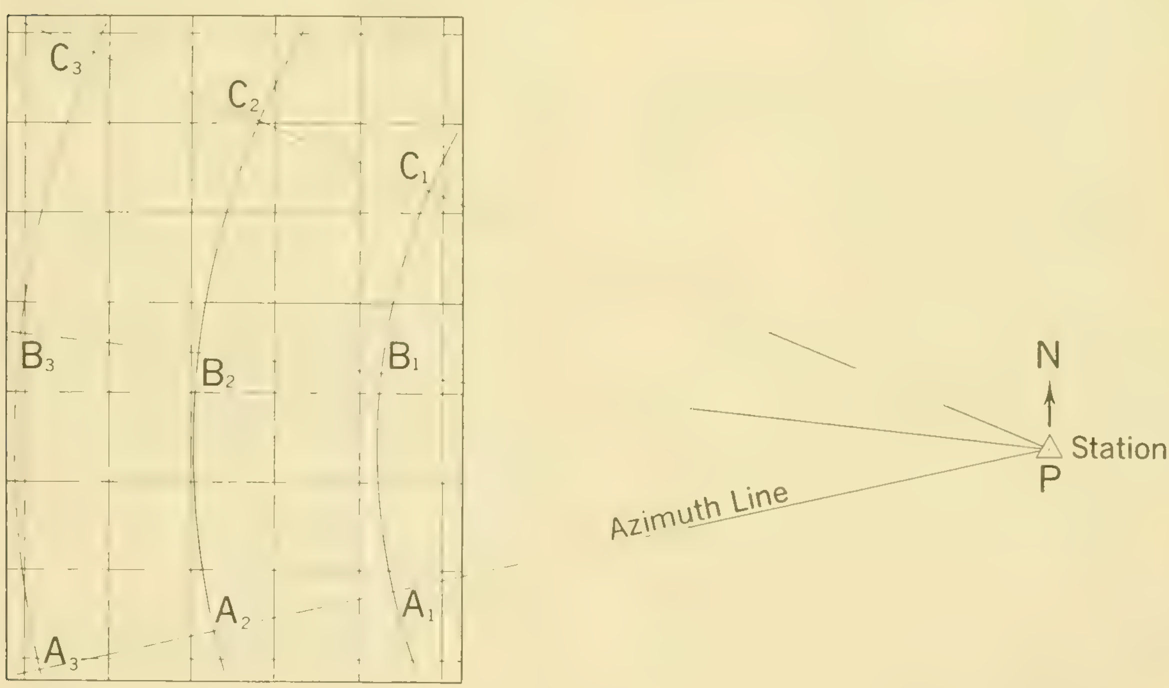

FIGURE 51.—Principle of drawing distance arcs when the station is off the sheet.

ferred to a base line which is a multiple of 400. The value of the baseline is noted at each change by such an expression as 400 plus, 800 plus, etc., (see 3–83).

5–32 Care of fathograms.—The fathogram is the original record of the soundings and must be carefully preserved (see 1–37). Fathograms of record shall be accordion-folded into flat 10-inch panels and put in manila envelopes or bellows files properly labeled as to sheet number, sounding vessel, day letters, and dates for enclosures.

Fathograms shall be carefully packaged and forwarded by registered mail or express. They shall not be transmitted in the same shipment with the smooth sheet or sounding record books (see 7–24.).

5–33 Position fixing.—In order that a sounding may be charted in its correct latitude and longitude or in proper relation to the adjacent shore, it is necessary to determine the position of the sounding vessel at frequent intervals. If the vessel is proceeding at a constant speed, and on a fixed course, the soundings between positions can be spaced and plotted quite accurately. The position is generally determined by one of two methods: (1) Three-point sextant fixes; or (2) simultaneous measurement of two distances to shore stations. Occasionally a position may be expressed as an estimated distance and direction from a nearby signal or other known point.

5–34 Position identification.—For proper identification, hydrographic positions shall be numbered consecutively, starting with number 1 for each sounding vessel at the beginning of each day, and each day's work shall be identified by a letter, or combinations of letters assigned in alphabetical order (see 1–31). When hydrography is continuous, on a 24-hour basis, the first position after midnight shall be considered to start a new day and shall be numbered and lettered accordingly, except for long dead reckoning lines which are often given one day letter for each line.

When a sounding line is continued from one sheet to another and the last position on one sheet is the same as the first position on the other, the position shall be identified by number and letter appropriate to each sheet.

5–35 Day letters.—Each day's hydrography shall be identified by a letter assigned in alphabetical order starting with the letter A on each sheet and omitting the letters O and I. Until the alphabet is exhausted, single letters shall be used. After the letter Z, double letters shall be used, the first series being AA, BA, CA, etc., the second series being AB, BB, CB, etc., and likewise for successive series as needed.

Capital letters of one color shall be used to identify the hydrography surveyed from the ship or major survey vessel of the party; and lower case letters to identify the work of the launches or supplementary vessels of the party, a different color being assigned to each unit. A separate series of day letters shall be used to identify the work of each sounding vessel in the records and on the sheet. The colors to be used to ink the position numbers and day letters are purple, blue red, and green in that order of preference. The day letter in the sounding record shall be recorded in the color assigned that unit (see 1–31).

5–36 Frequency of positions.—The frequency of positions along a sounding line is influenced by several factors: the scale of the survey; line spacing; speed of the survey vessel; conditions of wind and current; and type of control being used (see 1–30). The maximum distance between successive positions on a sounding line should be about 1½ inches on the survey sheet, regardless of the scale. Positions should be obtained at regular intervals as this will be of advantage in plotting and spacing soundings and will aid in detecting errors in plotting.

When sextant fixes are used to control the hydrography, positions must be obtained more frequnetly where there is difficulty in keeping on line due to currents or where lines must be closely spaced. Positions may be

taken less frequently when steering ranges or when the lines are being run parallel to distance arcs. In areas of even bottom the distance between successive fixes along distance arcs may be slightly increased, but should never exceed 2 inches on the sheet.

In most cases a survey ship or launch proceeds along a sounding line at full speed. If the scale of the survey is small, the positions may be taken at intervals of several minutes, however, if the scale is large the intervals will be short and it may be necessary to reduce the speed of the vessel.

Sextant fixes can be observed and plotted very rapidly particularly where the fixes are strong and the signals are nearby. Recording of an excessive number of fixes should be avoided in order to reduce the labor of smooth plotting the survey. For example, a 1½-minute interval between fixes should not be used if a 2-minute interval is adequate.

In addition to the evenly spaced positions along a sounding line, numbered positions shall be recorded under all of the following circumstances, whether or not accompanied by control data, when this is practicable:

(a) At the beginning and ending of each line.

(b) Whenever the speed of the sounding vessel is changed appreciably.

(c) At all changes of course larger than 10°. When the vessel is small and the change in course is immediately effective, the position may be taken at the middle of the change. Otherwise, a position should be recorded just before the course is altered and just as soon as the vessel is on the new course.

(d) At each detached sounding, particularly when determining the least depth on a submerged feature.

(e) Each time a bottom sample is obtained with the vessel stopped, whether or not a sounding is recorded.

(f) Each time a position is fixed for any purpose in connection with the survey, such as for determining the position of a floating aid, an obstruction, or a signal. Positions recorded for the sole purpose of calibrating electronic equipment need not be numbered.

5–37 **Three-point sextant fix.**—Most inshore hydrographic surveys are controlled by the three-point fix method using sextants to measure two angles between points whose geographic positions are known (see 3–13). The position at which the angles are observed is fixed by the intersection of two circles generated by the loci of the angles. In practice the three-point problem is solved mechanically by using a three-armed protractor. The fix is strongest when the circles intersect at an angle of about 90°, and is weakest when the two circles approach coincidence.

5–38 **Selection of objects.**—An experienced hydrographer can estimate the strength of a fix at a glance, and is able to select the strongest available fix immediately. Beginners often have difficulty is visualizing the problem and may select a weak fix when good ones are available. The following general rules apply in selection of objects to be used:

(a) The strongest fix is when the observer is inside the triangle formed by the three objects. And in such case the fix is strongest where the three objects form an equilateral triangle, the observer is at the center, and the objects are close to the observer.

(b) The fix is strong when the three objects are in a straight line, or the center object lies between the observer and a line joining the other two, and the center object is nearest to the observer.

(c) The sum of the two angles should not be less than 50°, better results being obtained when neither angle is less than 30°.

(d) The fix is strong when two objects a considerable distance apart are in range and the angle to the third is not less than 45°.

(e) A fix is strong when at least one of the angles changes rapidly as the survey vessel moves from one location to another.

(f) Small angles should be avoided as they result in weak fixes in most cases and are difficult to plot. However, a strong fix is obtained when two objects are nearly in range and the nearest one is used as the center object. The small angle must be measured accurately.

(g) The distance between the center ob-

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CORRECTIONS TO THE HYDROGRAPHIC MANUAL

This manual will be maintained by issuance of corrections and/or addition of new material as necessary. Changes shall be inserted in the proper places upon receipt, and a record of such entry shall be made in the spaces provided below.

Change No.	Date of change	Date entered	Signature of person entering change

PREFACE

This edition of the Hydrographic Manual is issued to serve as a guide in the execution and processing of hydrographic surveys. Since Special Publication 143 was issued in 1942 there has been rapid development in control systems and echo sounders which renders that work obsolete in some respects. Although parts of the present text are carried forward from Special Publication 143, much useful information has not been repeated and copies of the 1942 edition should not be destroyed but should be retained for reference purposes.

The subject matter in this manual is identified by a numbering system in which the first number identifies the chapter and the second number identifies the section in the chapter. Cross references are entered by numbers in the same manner; for example the notation (see 1–26) refers to Chapter 1, Section 26.

This edition of the Hydrographic Manual has been compiled with the assistance and advice of many officers and personnel in the office and the field. Special credit is due Mr. G. F. Jordan who wrote the first draft of Chapter 6. The Smooth Sheet; to Mr. R. H. Carstens who reviewed a large part of the manual and contributed much valuable information; to personnel from the Electronics Laboratory for their contributions to Chapter 3; to the officers who reviewed the manuscript; and to Mr. C. E. Cook for his assistance in preparing the index.

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1. GENERAL REQUIREMENTS

1–1 Introduction.—To provide charts and related information for marine and air commerce, and to provide basic data for engineering and scientific purposes, and for other commercial and industrial needs, the Coast and Geodetic Survey is authorized by law to conduct a variety of field and office activities. These include topographic surveys of the coastline and hydrographic surveys of United States and Territorial waters. This manual is intended to describe the field operations required to accomplish hydrographic surveys. Field methods and standards which are adequately described in other Bureau manuals are not covered in this manual except by appropriate references.

The publication of an adequate series of accurate nautical charts is undoubtedly the Government's greatest single contribution to safety at sea and the growth of the merchant marine and other waterborne activities. There are those who believe that hydrographers make a fetish of accuracy in survey operations, that many unnecessary refinements are attempted, and that some of the final results are only "paper accuracies." Few mariners attempt to evaluate a nautical chart. They have a simple faith in its accuracy. Where no dangers are shown they believe that none exist. The hydrographer by patient and relentless attention to every detail must justify the mariner's boundless confidence in his work.

Fundamentally, hydrographic surveying is that branch of physical oceanography employed to define the configuration of the bottom of oceans and navigable waters of lakes, rivers, and harbors. In a much broader sense, the science embraces a wide variety of activities, all of which are necessary for compilation of nautical charts and related publications designed to provide all information required for safe navigation.

1–2 Nautical charts.—The most important criteria by which the value of a nautical chart may be judged are its accuracy, adequacy and clarity. A lack of any one of these may result in a marine disaster with consequent loss of life and property. Except for blunders in compilation, accuracy depends directly on the quality of field surveys; the hydrographer and cartographer are equally responsible for the adequacy, but the cartographer alone can embody clarity in a chart.

Accuracy of a nautical chart is dependent on the accuracy and adequacy of the hydrographic surveys from which it is compiled; it cannot be more accurate. The increasing size and draft of merchant vessels, growth of submarine activity, and recent developments in exploitation of submerged lands are combining to make the standards for hydrographic surveying ever more strict. In recent years new surveying and navigational equipment have been devised and former ones developed to greater perfection. Hydrographers must be alert to keep abreast of advancing electronic and other scientific developments which can be adapted to survey uses.

Specifications for Hydrographic Surveys

This part of the manual contains a summary of the general specifications for hydrographic surveys. Each subject is treated in detail in other parts of this manual or in other Coast and Geodetic Survey manuals.

1–3 Project instructions.—The field operations of a hydrographic survey in a specified area are considered a project and each project is assigned a number, such as CS-406, the letters being the abbreviation of Coastal Surveys. Project instructions are written for each numbered project to supple-

ment the published manuals. The details of the instructions will vary from specific to general, depending on the locality and nature of the project. For a combined operation project, the instructions will treat of the following subjects: project limits, control, topography, hydrography, tides, magnetic observations, and miscellaneous. Occasionally additional subjects are included, such as special detailed oceanographic investigations, current observations, and wire drag surveys. (See Chapter 2.)

1–4 **Data to start survey.**—Copies of all prior survey data that are considered necessary in connection with the combined operations of the project will be furnished with the project instructions. These will include: descriptions and geographic positions of all triangulation stations and recoverable topographic stations; copies of prior hydrographic and topographic surveys; descriptions and elevations of tidal bench marks; and information as to dangers reported. If prior photogrammetric surveys have been made, copies of the manuscripts and photographs will be furnished.

1–5 **Presurvey review.**—The Chart Division will prepare a presurvey review for each hydrographic survey project (see 6–108). All prior records and the largest scale charts of the project area are examined. Critical soundings and charted data which are unverified or questionable will be indicated and described on the charts. All items must be thoroughly examined in the field to prove or disprove their existence, and each item shall be specifically mentioned in the descriptive report to accompany the survey. The presurvey review is not intended to relieve the Chief of Party or the hydrographer from a responsibility to compare the results of the survey with the features shown on the largest scale chart of the area.

1–6 **Scale of surveys.**—One of the rules of chart construction is that data on a smooth sheet shall seldom, if ever, be enlarged to the scale of a published chart. The scale adopted for a survey shall be larger than—preferably at least twice as large as—that of the largest-scale published or proposed chart of the area.

The basic scale for hydrographic surveys of the Coast and Geodetic Survey is 1:20,000 and almost all other scales used have a simple relationship to it. No inshore survey adjacent to the coast shall be plotted on a scale smaller than 1:20,000, except by authority of the Director.

All important harbors, anchorages, restricted navigable waterways, and many parts of the coast where dangers are numerous shall be plotted on scales of 1:10,000 or larger.

1–7 **Sheet Layout.**—Prior to beginning field work, a hydrographic sheet layout (Figure 2) shall be prepared and forwarded to the Washington Office for record and approval. The layout should generally be made at the scale of the largest scale chart covering the project area. Each sheet should be laid out to include as large a water area as practicable, at the same time providing for adequate overlap with adjacent sheets and ensuring that all required control stations will be included (see 2–20). The overlaps of sheets should be such that soundings will seldom be plotted closer than 3 inches to the edge of a sheet.

Sheets containing small detached areas of hydrography shall be avoided if practicable. This can usually be accomplished by placing a subplan, or inset, on the smooth sheet at the same or an enlarged scale (see 6–6).

All hydrographic sheets shall be laid out so that the projection lines are approximately parallel with the edges of the sheet, except when such a layout is extremely uneconomic or impractical. Skewed projections should not be used without prior authority of the Director.

1–8 **Sheet sizes.**—The standard size for all hydrographic smooth sheets is 36 by 54 inches. Chiefs of Party are authorized to increase the size of the sheet to 36 by 60 inches in exceptional cases, but approval shall be obtained from the Director before using a larger sheet. The maximum size,

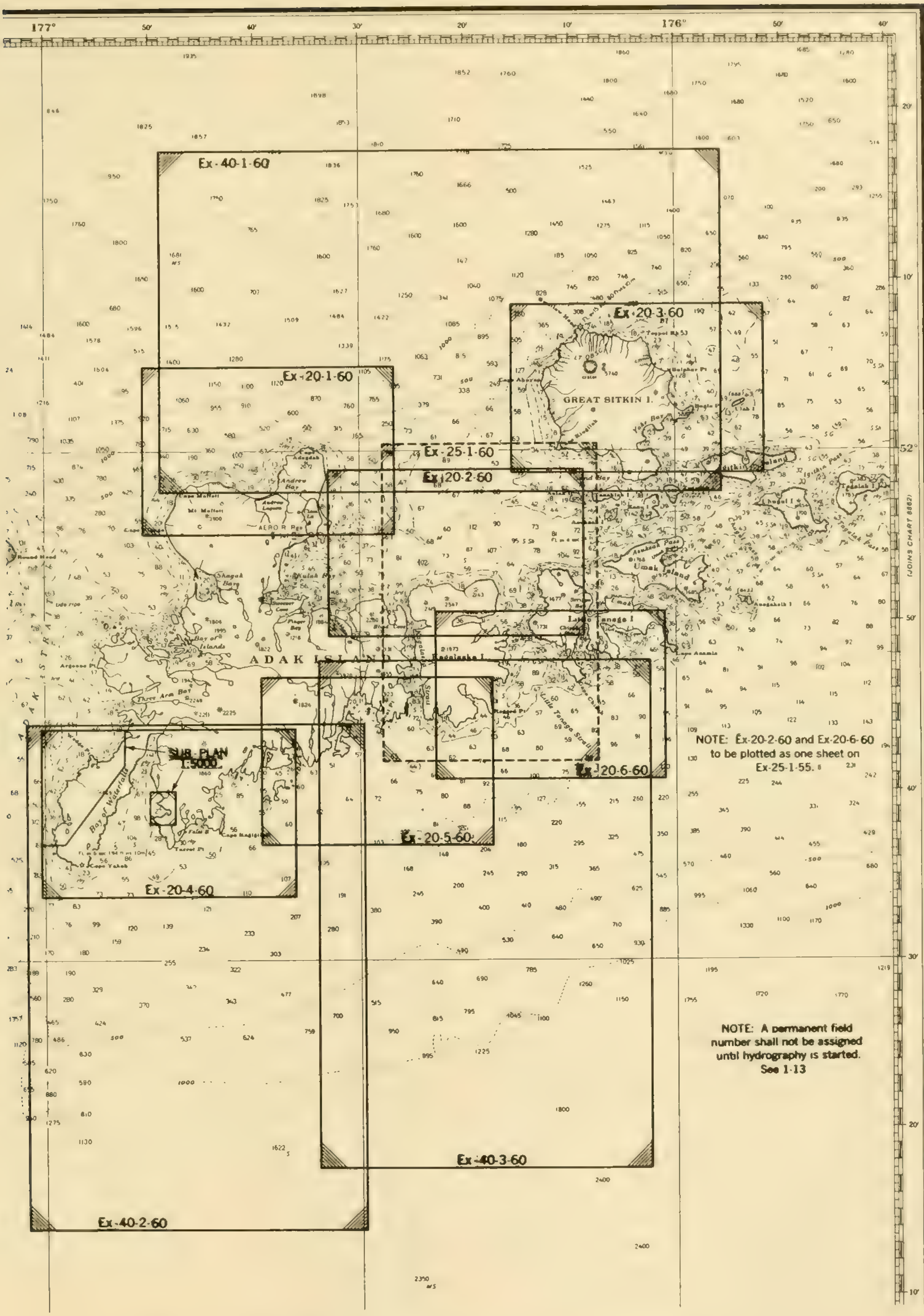


FIGURE 2.—Typical layout of hydrographic survey sheets showing field numbers.

which must never be exceeded under any circumstances, is 42 by 60 inches.

1–9 Boat sheet paper.—Boat sheets shall be prepared on first-quality white drawing paper mounted on muslin, or on aluminum-mounted paper furnished by the Washington Office. The muslin mounted sheets should be well seasoned before the projections are drawn.

1–10 Boat-smooth sheet procedure.—Hydrographic parties are authorized and encouraged to use a combination boat and smooth sheet where practicable. This method of field plotting will avoid the necessity for replotting the positions and thus reduce the time and effort required to obtain a smooth copy of the survey (see 5–5 and 6–45).

When this method is used for an electronically controlled survey the final corrections, as far as is practicable, shall be applied to the measured distances before they are plotted. The records or descriptive report shall show any plottable discrepancies between values used to plot the positions and the final corrected values of the measured distances. A transparent cover shall be placed over the sheet during position plotting.

All procedures other than position plotting shall conform with instructions for smooth plotting a hydrographic survey. (See Chapter 6.)

1–11 Projections.—The Bureau has adopted for all surveys a projection known as the Coast and Geodetic Survey polyconic projection and all surveys must be plotted on this projection. North shall always be considered the top of the sheet, whether or not the projection lines are parallel to the edges of the sheet. In plotting and inking boat sheets all lettering and numerals of any kind shall be so lettered as to be read from the south. All boat sheet projections shall be constructed in the field unless the project instructions specifically state that they will be furnished by the Washington Office.

1–12 Construction of projection.—The construction of a polyconic projection is a simple problem, but extreme accuracy and care are required. Instructions and data for construction of a projection are contained in Special Publication No. 5, The Polyconic Projection Tables. The projection must be constructed and checked in one continuous operation and as rapidly as possible and consistent with accuracy required (see 5–6 and 7). The sheet should not be exposed to the direct rays of the sun, and the projection should be made during a period of weather when conditions of temperature and humidity are stable and about average for the conditions under which the sheet is to be used.

The projection must be checked the same day it is constructed and immediately following construction. Rubber stamp No. 42, Hydrographic Survey, shall be impressed at an appropriate place near the right edge of the sheet. Entries should be made in all the applicable spaces of the stamp.

The projection intervals between the meridians and parallels to be shown on a survey sheet depend on the scale used and shall be as specified in Table 1.

The projection is constructed in pencil. It must be verified and all control stations plotted, by dms and dps, and checked while the lines are in pencil. The projection lines should then be inked as fine solid black lines 0.15 mm. in width extending entirely across the sheet.

TABLE 1.—Projection line intervals for various scales

Scale of Survey	*Projection Line Interval*
1:2,000 and larger	Every 5 seconds.
1:2,001 to 1:3,000	Every 10 seconds.
1:3,001 to 1:6,000	Every 15 seconds.
1:6,001 to 1:12,500	Every 30 seconds.
1:12,501 to 1:25,000	Every minute.
1:25,001 to 1:60,000	Every even minute.
1:60,001 to 1:125,000	Every 5th minute.
1:125,001 to 1:250,000	Every 10th minute.

1–13 Field numbers.—For convenient reference while a survey is in progress, each hydrographic sheet shall be assigned a field number. A permanent field number shall not be assigned to any sheet until hydrography is started on the sheet; and the number shall not thereafter be changed even though the survey is completed by another vessel. Unused boat sheets constructed by or for one survey unit and subsequently transferred to another unit shall be assigned a field number by the latter when the survey is started. The final two digits of the field number represents the calendar year in which the survey was initiated and are not to be changed if the survey extends into the following calendar year.

The field number shall be composed of letters, usually the first two letters of the ship's name, which identify the vessel or party making the survey, and a series of numbers separated by hyphens to indicate the scale of the survey, the number of the sheet in a series at that scale, and the year in which the survey was begun. The following examples are typical of the numbering system to be used:

EX–2.5–1–58 = EXPLORER — scale 1:2,500—first sheet in the series at that scale—survey begun in 1958.

ECFP–10–11–59 = East Coast Field Party —scale 1:10,000—11th sheet—1959.

LJ–25–2–60—LESTER JONES = scale 1:25,000—2nd sheet—1960.

PI–200–4–60 = PIONEER—scale 1:200,-000—4th sheet—1960.

Completed surveys are normally referred to by their registry numbers in correspondence

1–14 Registry numbers.—At the end of each season, or at such times as circumstances dictate, the Chief of Party shall request from the Washington Office the assignment of registry numbers to completed hydrographic surveys, or surveys which will be completed during the season. Numbers should not be requested for incomplete surveys.

1–15 Horizontal control.—The control for all hydrographic surveys, except track line and reconnaissance surveys, shall be based on triangulation of third order accuracy or higher (see 4–1). All established triangulation stations in a project area shall be searched for and appropriate reports submitted. If new triangulation is required, the field work shall be accomplished in accordance with instructions and specifications contained in Special Publication No. 247, Manual of Geodetic Triangulation. Points selected for the location of electronic shore stations shall be located by triangulation or traverse of third order accuracy or higher.

1–16 Photogrammetric surveys.—Nearly all topographic surveys are now being made photogrammetrically, and the hydrographic party will be furnished photographs, manuscripts, and other data to support hydrographic operations. Except in Alaska and other remote areas, the Photogrammetry Division will accomplish all field work required to produce advance manuscripts, and, in most cases, will assign a photogrammetrist to build and locate signals to provide visual control for hydrography.

Outside continental United States, hydrographic parties shall establish and identify control and accomplish the field inspection required in advance of photogrammetric compilation. On occasion the party may be furnished preliminary manuscripts which are based on office identified control. See Chapter 4 for a discussion of manuscript classifications and uses.

A marked triangulation station can seldom be identified on a photograph and substitute points in the immediate vicinity are used. (See Photogrammetry Instruction 22, Revision 1, dated 1 November 1959.) At least two such points should be identified and pertinent information recorded on a Control Station Identification (C.S.I.) card (Form 152). Identification must be precise, as misidentified control will warp the compilation and will seriously affect the location of the supplemental photo-hydro stations (see 4–11).

Supplemental control for hydrography shall be located by photogrammetric methods

wherever practicable (see 4–18). The stations shall be established in accordance with Photogrammetry Instruction 45, Revision 1, dated 15 March 1954. Discrepancies in the location of photo-hydro stations should not exceed 0.5 mm. at the scale of the manuscript.

The Photogrammetry Instructions referred to in this section are part of a series which cover field operations in photogrammetric surveys. A new Topographic Manual, Part 1, will eventually replace them.

1–17 Planetable surveys.—Instructions for planetable surveys are contained in the Topographic Manual, Special Publication No. 144. Topographic surveys by planetable methods will seldom be required; however, the planetable shall be used to locate signals for control of hydrography wherever expedient to supplement the photogrammetric work (see 4–9). When stations are located by planetable, 90 percent of them shall be within 0.5 mm. of their true geographic positions and no station shall be in error by more than 0.8 mm. as measured on the topographic sheet.

All graphic control and other planetable surveys shall be made on 24 by 31-inch aluminum-mounted sheets as furnished by the Washington Office. The scale of the survey shall never be smaller than the largest scale hydrographic survey of the same area.

1–18 Signal location by sextant angles.—On occasion it is necessary to locate a signal by sextant angles (see 4–26). In such cases the position of the signal shall be determined by (1) a three-point fix at the station with a check angle; or (2) three sextant cuts giving a good intersection. The geographic position of the station should not be in error by more than 1.0 mm. The strongest available fix should always be used and should include triangulation stations where practicable. Stations located by sextant angles shall not be used to locate other stations.

1–19 Electronic control.—The shore stations for electronic control of hydrographic surveys shall be established at triangulation stations, or the principal antenna shall be located by triangulation of at least third order accuracy. Distance arcs at fixed positions should not intersect at angles less than 30° or more than 150°. Three electronic systems are authorized for use in position fixing: Shoran, Electronic Position Indicator (EPI), and Raydist.

(a) Shoran is a line-of-sight system and should rarely be used at greater distances (see 3–33 to 47). The system requires very careful and repeated calibration. At least one calibration for each ground station shall be obtained for each 5 consecutive days. Calibrations shall be obtained at various distances including the minimum and maximun distances used in hydrography. Whenever changes are made in the equipment, the time of change must be recorded and new calibrations observed. A zero check shall be observed and recorded at each calibration, at the beginning and ending of each day's work, and at intervals of 1 to 2 hours while surveys are in progress. Special manuals are provided containing instructions for installation and servicing of Shoran equipment.

(b) EPI equipment is designed for use on large survey ships to control offshore hydrography at maximum ranges of about 500 nautical miles (see 3–23 to 32). It shall not be used to control surveys at a scale larger than 1:100,000. The equipment shall be calibrated at the beginning and end of each trip, when changes are made in the equipment, after each period when the equipment is not in operation, and at other convenient times. Detailed instructions for the operation and maintenance of EPI equipment are contained in Special Publication No. 265A, EPI Manual.

(c) The standard Raydist equipment is designed for use in survey vessels of any size larger than launches (see 3–48 to 61). A smaller transistorized equipment can be used in small survey boats. Raydist may be used to control surveys at any scale normally used by the Bureau. The phasemeter dials must be set at a known position. Partial lane corrections to measured distances shall be applied when they can be plotted at the scale of the survey. The lane count must

be continually monitored, and if lanes are gained or lost appropriate corrections applied. The equipment should be reset at a known point as soon as practicable. The maximum usable range of Raydist has not been determined, but usable signals have been received at distances in excess of 250 miles.

1–20 Plotting control.—When muslin-mounted boat sheet paper is used, there is always a possibility that the projection will soon be distorted to some extent by changing atmospheric conditions. If electronic control is to be used, the distance arcs should be plotted as soon as possible after the projection has been checked (see 5–11). When the boat-smooth sheet procedure is to be used, it is essential that the amount of distortion be determined and proper corrections applied to measured distances before the arcs are drawn. Three positions on three well-distributed arcs shall be computed and plotted and intermediate points plotted by mechanical subdivision or by means of a template. The arcs are then drawn in colored ink with a beam compass, or along the edges of plastic arcs of appropriate radius. When aluminum-mounted paper is used, there should be little or no distortion and rapid plotting of arcs is less urgent. Distance units (miles, lanes, or microseconds) shall be numbered in matching colors on the arcs, but should be near the ends of the arcs or in areas where no soundings will be plotted.

The positions of stations to be used for visual control of hydrography shall be plotted before the projection is inked. Triangulation stations shall be plotted by dms and dps and checked. Stations located in the field on photogrammetric manuscripts shall be pricked through to the boat sheet after correct registration of the projections has been made. If the stations are shown on the blueline prints of the manuscripts, they shall be transferred by burnishing, adjusting the projections as necessary to compensate for distortion. Stations located by planetable surveys are transferred by tracing paper and similar adjustments made. All such transfers shall be verified before the station symbols are inked.

1–21 Station symbols and names.—Each station used for control of the hydrography shall be identified on the boat sheet by its appropriate symbol and name, both inked in the color specified. The actual station point is a fine needle hole, the edges of which are blackened by carefully rotating a sharp, hard pencil point in the hole. The symbols and colors shall be according to the following scheme and Figure 79:

(a) Triangulation and traverse stations shall be identified by red equilateral triangles, 4.5 mm. on a side, symmetrically placed around the station point with the base of the triangle parallel to a line of latitude.

(b) Topographic stations, whether located by planetable or air photographic surveys, shall be identified by red circles 3 mm. in diameter.

(c) Hydrographic stations (stations located by sextant fixes or cuts) shall be identified by blue circles 3 mm. in diameter.

(d) Supplemental stations which have been spotted by the hydrographic party from details of the photographs or air photographic survey shall be identified by green circles 3 mm. in diameter.

(e) Electronic control stations shall be identified by the symbol appropriate for the method of location and a circle about 5 mm. in diameter in a color corresponding to the distance circles drawn from it.

All station names shall be inked on the boat sheet in vertical letters with the overall height of the upper case letters not to exceed 3 mm. and in the same color as the symbol the name identifies. Names should never be placed in water areas.

1–22 Transfer of topographic detail.—The shoreline and alongshore detail shall be carefully transferred to the boat sheet. After the transfer has been verified, the shoreline shall be inked with a continuous solid black line about 0.4 mm. wide. The rocks, limits of kelp or foul areas, and similar detail lying outside the highwater line

shall be inked in blue, except that offshore islets and rocks whose positions have been definitely established shall be inked in black. Photogrammetric compilations will often show the approximate limits of shoals and channels. These limiting lines shall be transferred to the boat sheet and indicated by fine dash blue lines.

1–23 Verification of alongshore details.—The location of rocks, limits of foul areas, and other details in the area seaward from the highwater line which have been transferred from the manuscripts must be verified by the hydrographer (see 5–67). The symbols which have been inked in blue shall be inked black when verified. If the position of an offshore rock is changed by the hydrographer, or if it is proved that there is no rock at the position shown, a note shall be made in the record and on the boat sheet. Failure to reconcile and explain differences between the manuscript and the hydrographic survey results in unnecessary delays and difficulties in verification and review (see 6–89).

Each isolated bare rock or rock awash must be located or the position verified and its height determined by the hydrographer. The important rocks of a group or rocky area shall likewise be located and elevations determined.

1–24 Sounding lines. — A hydrographic survey is accomplished by running a predetermined system of sounding lines in an area. A system must be chosen that will delineate the submarine relief in the most thorough and economic manner (see 5–19 to 22). A series of evenly-spaced, parallel sounding lines is the best method to accomplish this. In general, the sounding lines should be normal to the depth curves, but it is frequently more advantageous to adopt some other system. For the development of steep features, such as ridges or submarine valleys, the system of lines should cross the depth curves at an angle of approximately 45 degrees. A restricted channel should be developed by a system of lines parallel to the axis of the channel. A system of straight lines is customarily used; however, when hydrography is controlled by Shoran or Raydist, better control of the sounding vessel is maintained by running lines parallel to the distance arcs, especially in areas where strong currents are encountered.

1–25 Line spacing.—The spacing of sounding lines required to properly develop a given area depends upon the depth of the water, the character of the bottom, the scale of the survey, and the general nature of the area (see 5–25 to 28). Harbors, channels, anchorages, and shoal areas which may be dangerous to navigation, should be surveyed by a system of closely-spaced lines, for example, 50 to 100-meter lines on a 1:10,000 scale. As the depth increases, the line spacing is increased to a width of 5 miles in depths greater than 1,000 fathoms. In all cases, the line spacing should be reduced as necessary to adequately delineate the bottom configuration. The low-water line should be delineated if possible; however, sounding lines are not required in extensive areas which bare at low water.

1–26 Crosslines.—The regular system of sounding lines shall be supplemented by a series of crosslines (see 5–23) for the purpose of verifying the accuracy of the survey and the control as follows:

(a) All launch and small boat hydrography shall be verified by crosslines to the extent of 8 to 10 percent of the principal system of sounding lines exclusive of development.

(b) All ship hydrography in areas of fairly regular bottom shall be verified by crosslines to the extent of 5 to 6 percent of the regular system of lines exclusive of development. In areas where the principal system of sounding lines is generally parallel to the depth curves, the crosslines shall be 8 to 10 percent of the regular system.

(c) Crosslines need not be run in areas of very irregular submarine relief because in such cases they are of little value for checking purposes.

(d) Crosslines shall be run at an angle of 45 to 90 degrees with the regular system.

(e) In areas of regular bottom, a frame-

work of crosslines should be run first to establish control for the regular system of lines. The crosslines should be very accurately controlled, and the sounding equipment in perfect operating condition. The soundings should be reduced for actual tide, if possible. Daily comparison at crossings should be made. Serious discrepancies will indicate an incorrect reducer, a fault in the control, or faulty operation of the echo sounder and should be investigated at once.

1–27 Indications of shoals.—A hydrographic survey may not be considered complete and adequate until there is reasonable assurance that all dangers to navigation and shoals existing in the area have been found and the least depths on them determined. After the feature has been developed by closely-spaced sounding lines, each critical area must be thoroughly examined to determine the least depth (see 5–69). It is obviously impracticable in many localities to examine every shoal indication. In selecting soundings to be further examined, the importance of the locality and the types of shoals or dangers to be expected must be considered. Hydrographers should be guided by the following considerations:

(a) In general depths of 10 fathoms or less in a navigable area, all indications should be examined.

(b) All shoal indications rising more than 10 percent from the general depth should be examined.

(c) The nature of the bottom should be considered. If it is rocky, there is more likelihood of a dangerous pinnacle. If the bottom is sand or mud, there is little chance that a danger exists.

(d) The importance of the region from the point of view of navigation should be considered. All indications in channels and harbors should be examined. In areas of lesser importance, the number of examinations may be reduced.

1–28 Development of shoals.—The general spacing of sounding lines should give a methodical representation of the depths and generalized depth curves in the area and be sufficiently close to give indications, at least, of all banks and dangers therein. Every sounding of a depth slightly less than the average surrounding depths should be regarded as a definite indication of a possible shoal (see 5–68). The sounding lines should be "split" by running intermediate lines between the regular system of lines as necessary to develop these indications (see 5–69 and 70). When the regular system of lines discloses the limits of a shoal or bank, a supplemental system of closely spaced sounding lines should be run in a direction best suited to completely develop the feature; they may be parallel with the longer axis of the feature or in the form of radiating lines crossing at the center of a shoal of small extent. The development of the shoal indications furnished by the general system of lines is the most important part of the work and frequently the most extensive.

In areas where the bottom is visible, there is no particular difficulty in finding the least depth. In other areas the least depth may be determined by wire drag, by drift sounding, or "feeling" with a leadline, especially over kelp-covered rocky shoals.

The development of a shoal and search for the least depth frequently results in the running of lines which cannot be smooth plotted at the scale of the survey. Lines which add nothing to the data already recorded should be marked "not to be smooth plotted" in the sounding record (see 5–25).

1–29 Survey overlap at junctions.—An overlap of at least one sounding line shall be made with an adjacent survey except as specified below, and if the depths at the junction are not in agreement, the new survey shall be extended into the old until a satisfactory agreement has been reached (see 5–16, 6–73 and 91). If a reasonable extension into the other survey fails of agreement, an investigation should be made and a report submitted to the office with a request for further instruction.

The overlap specified herein shall apply to the following classes of surveys:

(a) All noncontemporary surveys;

(b) Contemporary surveys by a different survey party;

(c) Contemporary surveys made by the same party in different years; by different methods; or from different vessels, as the survey vessel and one of her launches;

(d) Surveys by other organizations.

Where the hydrographic survey is continuous in the same year, by the same method and by the same survey vessel, junctions between adjacent sheets may be made by spacing the hydrography just as it would have been spaced had the two been combined in one sheet.

1–30 Position frequency.—The position of the sounding vessel must be determined at intervals which will permit accurate plotting of the sounding line. Obviously a knowledge of the depth is useless for charting purposes without a knowledge of the geographic position at which the depth was measured. The maximum distance between consecutive positions on a line should be about $1\frac{1}{3}$ to $1\frac{1}{2}$ inches on the survey sheet, regardless of scale or type of control. Positions should be obtained at regular intervals, the time between fixes being a function of speed and scale (see 5–36).

Positions should be recorded under all the following circumstances when this is practicable:

(a) At the beginning and end of each line;

(b) When the speed of the sounding vessel is changed appreciably;

(c) At all changes in course larger than 10 degrees;

(d) At each detached sounding.

The record shall show the exact clock time of each position and all data necessary to plot the position.

Positions are determined by electronic measurement of distances from fixed stations or by the three-point fix method using sextant angles. In the first case, the position is plotted by intersection of two distance arcs. Strength of the fix is determined by the angle of intersection of the arcs and is strongest when the angle is 90°. Intersection angles less than 30° or more than 150° are considered weak and should rarely be used. In the second case, the position is determined by the intersection of circles generated by loci of the sextant angles. This problem is solved mechanically by use of a three-arm protractor. The strength of the three-point fix depends on the angle of intersection of the two circles and is strongest when this intersection approaches 90°. It is weakest when the position is near or on a circle which passes through the three fixed points. The hydrographer should generally select the strongest fix available (see 5–38). Sextants should always be properly adjusted and electronic equipment correctly calibrated.

1–31 Position numbering.—The positions for each day's work on a hydrographic survey should be numbered consecutively. Each day's work shall be identified by a letter, or combination of letters assigned in alphabetical order, starting with the letter A on each survey sheet (see 5–34 and 35). Capital letters of one color shall be used to identify the hydrography accomplished by the ship or major survey vessel of the party; and lower-case letters to identify the work of launches or other small boats of the party, a different color being assigned to each separate unit.

Until the alphabet is exhausted, a single letter shall be used for day letters, omitting O and I. After the letter Z, double letters shall be used, the first series being AA, BA, CA, DA, etc.

The colors to be used to ink the position numbers and day letters are purple, blue, red, and green, in that order of preference. Neither black nor yellow shall be used for this purpose.

The inked numbers shall be small enough that they cannot be mistaken for soundings on reproductions of the boat or smooth sheet.

1–32 Sounding records.—The Soundings Record Book (Form 275) shall be used for recording all hydrographic work (see 5–84 to 99) except wire-drag surveys, for which Form 411 shall be used. A separate set of consecutively-numbered sounding volumes shall be kept for each hydrographic sheet.

If work is done by more than one unit in the area covered by the sheet, a temporary number shall be assigned to each volume. After completion of all work on the sheet, the records of each vessel shall be grouped in proper order, the various groups combined, and the complete set of records shall be numbered consecutively and permanently. The field number and the registry number of the hydrographic survey shall be clearly marked in pencil on the cover label of each volume.

On ships which use a magnetic compass for hydrography the deviation table for the steering compass shall be entered on page 1 of each set of records, and in the proper record (with reference to date) if changed during the course of the survey. This is not necessary for launches and small boats using portable compasses.

An index of all objects such as signals, survey buoys, aids to navigation, landmarks for charts, rocks, and breakers, the positions of which have been located by sextant angles, shall be entered as follows: if a separate volume contains all such data, the index shall be entered on Page 2 of that volume; if the data are interspersed through the sounding records, the index shall be entered on Page 2 of Volume I, giving the volume and page numbers on which are recorded all data for the location of any given station or object.

A separate index of special hydrographic information such as currents, tide rips, overfalls, bottom samples, and calibrations of electronic equipment shall be entered on Page 2 of Volume I.

Certain information should be recorded at the beginning of each day's work, including names of personnel engaged in the operation, instruments in use to control the survey and to obtain soundings, data ralative to adjustment of instruments, bar check and other calibrations, if any, and notes on state of weather, wind, and sea. Changes of personnel or instruments should be noted when they occur.

The heading on each page should be filled in completely. Rubber stamps may be used for some of the required entries.

The statistics for each day's work shall be entered at the end of each day. The sextants and clock used shall be verified and the fact noted. The processing stamp shall be impressed at the end of each day's work and the location of the tide gage for control of the hydrography shall be entered.

In the remarks column shall be entered all additional information required for the proper understanding and correct plotting of the work, including the following:

(a) Record the latitude and longitude of the beginning and ending of each line; or distance and direction from a nearby signal.

(b) Record the latitude and longitude of detached positions on rocks, shoals, etc.

(c) When the sounding line passes close to any important feature such as islets, piers, rocks awash, breakers, buoys, etc., a bearing and estimated distance to the feature should be noted.

(d) Record changes in speed of the sounding vessel, or variation in echo sounder operations including phase, gain, or other adjustments.

(e) Limits of kelp or grass, existence of tide rips, or swirls, changes in wind direction and velocity should be noted.

(f) Full explanation must be given of all corrections, rejections and omissions in the record.

(g) Changes in personnel, procedures, or equipment shall be noted at the time the change is made.

Erasures shall not be made in the record at any time, all corrections being made by crossing out the incorrect entry.

Standard time shall be used in all hydrographic recording and the standard meridian shall be noted at the head of the "Time" column at the beginning of each day's work. Time shall be recorded by numbering the hours consecutively from 0ʰ (midnight) to 23 (11 p.m.).

1–33 Sounding interval.—Nearly all sounding are obtained by echo sounders which record a continuous profile of the bottom. Soundings are scaled from the graph at intervals which are determined

by the depth of water and scale of the survey. Soundings should be recorded at regular intervals and in sufficient numbers to provide a realistic representation of the sea bottom and submarine relief (see 5–29). Maximum depths in depressions and minimum depths on shoals shall be recorded as they occur and exact time or fraction of sounding interval noted in each case. The recording of an excessive number of soundings shall be avoided, as this results in wasted effort when the records are processed (see 6–59). When echo soundings are supplemented by hand lead, pole, or wire soundings, the record shall clearly indicate the method used.

When sounding in an area of uneven bottom the soundings observed at regular intervals shall be recorded on alternate lines of the sounding record. Odd interval soundings shall be interspersed as necessary to define the submarine topography.

1–34 Scanning fathograms.—The development of echo sounding recorders has provided an infinite increase in the number of recorded soundings. The problems encountered in verification of smooth sheets have also been multiplied. Many of these difficulties can be traced to improper interpretation of fathograms or to poor scanning techniques (see 5–122). Every fathogram must be carefully check scanned. A cursory inspection for peaks and valleys is not sufficient. The scanner must be particularly careful in scaling soundings in areas where kelp or grass all but obliterate the bottom trace. Soundings are often recorded in the wrong phase or are in error by 5 or 10 units, and strays or side echoes incorrectly recorded as true soundings.

Incorrect paper speed is an indication that the recorder was not operating properly, but it is not conclusive evidence that the recorded soundings are in error. Corrections to soundings should not be applied unless there is other proof that they are necessary. The check scanning is not complete until all significant variations from the initial setting have been scaled and entered in the record book.

The Chief of Party or other responsible officer should supervise and inspect this phase of operations. The necessity for careful and accurate scanning of fathograms cannot be overemphasized.

1–35 Sounding equipment.—The following listed sounding instruments shall be used in applicable depths:

(a) The sounding pole or lead line in depths too shoal for echo sounders, to supplement and verify echo soundings when sounding in areas containing kelp or grass, and to verify least depth on shoals, obstructions, and other dangers to navigation;

(b) EDO 255 or 808 type recorders operating on feet or fathoms scale in comparatively shoal waters, and to the limit of the scale in deeper waters when deep water recorders are not available;

(c) EDO-UQN in depths greater than 100 fathoms;

(d) Precision Depth Recorder (PDR), when available, in depths greater than 100 fathoms, and especially in depths beyond the limit of the UQN when operating at fast speed (expanded scale).

(e) Wire sounding machine for vertical cast comparisons, bottom sampling, and oceanographic work.

1–36 Echo sounder calibrations.—Most echo sounders used by the Coast and Geodetic Survey are calibrated for an assumed velocity of sound in seawater of 800 or 820 fathoms per second. Actual velocities shall be determined from serial temperature and salinity observations or by velocimeter and a table of velocity corrections computed (see 5–114 to 120). When the corrections to echo soundings are less than half of one percent of the depth they may be disregarded, but shall be used in all other cases.

When 808 type fathometers are used, phase comparisons shall be made at the beginning of the season and shall be repeated at least once each month during the season (see 5–112). Bar checks shall be made and recorded twice daily when sea conditions permit.

The EDO 255 may be used at a controlled

frequency to obviate the necessity of applying velocity corrections (see 5–120). The frequency meter reading shall be recorded at least once each hour. Bar checks shall be recorded twice daily when circumstances permit.

On large vessels where bar checks are not practicable, vertical cast comparisons shall be made and recorded at selected intervals when good casts can be obtained.

1–37 Fathograms.—Stamp No 31 shall be impressed at the beginning and end of each fathogram and all required information recorded to identify the record with the survey. Position fix marks shall be numbered consecutively and the day letter shown at every tenth position. Positions where the line begins, breaks, or turns about should be indicated (see 5–31). The phase or scale being used shall be indicated at each change. The PDR phase changes are automatic with base scales in multiples of 400 fathoms. The base must be indicated on the fathogram as 0 plus, 400 plus, 800 plus, etc.

Fathograms may be folded in accordion style or filed in rolls. The first method is preferred (see 5–32).

1–38 Depth units.—The depth unit of hydrographic surveys in the Atlantic Ocean, Gulf of Mexico and bodies of water tributary thereto shall be integral feet except for those offshore surveys which are entirely beyond the limits of charts whose depth unit is feet, in which case the depth unit of the survey shall be fathoms. In certain areas, such as the coast of New England, where echo sounders are operated on the fathom scale for most of the survey, the boat sheets may be plotted in fathoms, but the smooth sheet shall be plotted in feet unless otherwise directed by project instructions.

The depth unit of hydrographic surveys in the Pacific Ocean and bodies of water tributary thereto shall be fathoms, except that where the major part of the survey is within the limits of a chart whose depths are in feet, the smooth sheet shall be plotted in feet.

Although the depths in the sounding record may change from one unit to another within the area of the survey or within the same sounding records, they are all reduced to the unit to be used on the smooth sheet. Only one unit, fathoms or feet, shall be used on any boat or smooth sheet.

Soundings shall be recorded in integers, or to the nearest decimal part, according to Table 2 and the following rules:

(a) Echo soundings with the 808 Fathometer or EDO 255 for a hydrographic survey to be plotted in feet shall be recorded in FEET and DECIMALS except for (b) and (c);

(b) Where 808 type graphic-recording instruments, which can be operated to record in either feet or fathoms, are used in areas of irregular bottom, the first phase in feet shall be used to its limit, but, where numerous changes in phase would be required on the foot scale, fathoms shall be used for greater depths;

(c) Where EDO 255 graphic-recording instruments, which cannot be changed from one mode to another at will, are used, the recorder shall be operated on the foot scale to the maximum practicable extent in areas charted in feet. In areas where depths exceed the limit of the foot scale or the submarine features are very irregular, the instrument shall be operated on the fathom scale.

(d) All depths measured by echo-sounders for a hydrographic survey to be plotted in fathoms shall be recorded in **fathoms** and decimals except for (e);

(e) Where practicable, the shoal water soundings obtained by echo-sounders for a survey to be plotted in fathoms shall be obtained on the first phase in feet.

(f) Wire soundings shall be recorded in **fathoms** and **decimals.**

(g) Hand lead soundings interspersed with echo soundings shall be recorded in the same unit as the echo soundings.

(h) Hand lead soundings in depths less than 11 fathoms and pole soundings shall be recorded in **feet** and **decimals.**

1–39 Reduction of soundings.—Recorded soundings must be corrected for any depart-

TABLE 2.—Units for recorded soundings and corrections

Character of area or bottom	Depth range	For soundings in feet				For soundings in fathoms			
		In protected waters		In exposed waters		In protected waters		In exposed waters	
		Record soundings to the nearest	Enter corrections to the nearest	Record soundings to the nearest	Enter corrections to the nearest	Record soundings to the nearest	Enter corrections to the nearest	Record soundings to the nearest	Enter corrections to the nearest
On dangers and shoals									
On navigable bars									
In dredged channels	*fathoms*	*foot*	*foot*	*foot*	*foot*	*fathom*	*fathom*	*fathom*	*fathom*
At critical places in natural channels	0–11	0.2	0.2	0.5	0.2	0.1	0.1	0.1	0.1
In inside routes									
For delineation of the low-water line									
Over regular bottom	0–11	0.5	0.2	1.	0.5	0.1	0.1	0.2	0.1
On the least depths in irregular bottom									
Elsewhere in irregular bottom	0–11	1.	0.5	1.	0.5	0.2	0.1	0.5	0.2
On shoals and banks	over 11	1.	0.5	1.	0.5				
Elsewhere		1.	1.	1.	1.				
On shoals and banks and over regular bottom	11–31					0.1	0.1	0.2	0.1
Elsewhere						0.2	0.1	0.5	0.2
Over regular bottom	31–101					0.2	0.1	0.5	0.2
Elsewhere						0.5	0.2	0.5	0.2
Everywhere	101–150					1.	0.5	1.	0.5
When soundings are obtained with EDO type depth recorder:									
Over regular bottom	150–600					2.*	1.	2.*	1.
See (a) below	150–600					5.	2.	5.	2.
Fast speed	600–1800					5.	2.	5.	2.
Slow speed, see Note below	over 600					10.	4.	10.	4.
When Precision Depth Recorder is used:									
Over regular bottom	under 600					2.	2.	2.	1.
On steep slopes						5.	2.	5.	2.
Elsewhere	over 600					5.	2.	5.	2.

* On fathograms with lines at 5 fathom intervals read soundings to nearest 2½ fathoms but drop half-fathoms, thus last unit on soundings shall be recorded as either 0, 2, 5, or 7.

(a) With steep slopes and where an independent or check reading of the fathogram will not often agree with soundings recorded to the above lesser interval.

NOTE: On steep slopes where independent or check readings of the fathogram will not often agree when read to 10-fathom intervals, it may be necessary to allow greater latitude in the checking of the soundings.

ure from true depth due to the method of sounding, or to a fault in the measuring apparatus, and for the height of the tide above or below the plane of reference at the time of sounding (see 5–100 to 123).

Corrections shall be entered in the sounding volume in the same unit in which the soundings have been recorded. Parts of units shall be entered in decimals—fractions shall not be used.

A variety of corrections may be required including any or all of the following: draft, variation of the initial from the adopted index, settlement and squat, velocity (temperature, salinity, and pressure), tide, incorrect speed of echo-sounder operation, phase, incorrect radius of rotation of the stylus arm on 808 recorders and misalignment of paper. All data necessary to apply final corrections to soundings shall be accumulated as field work progresses.

Soundings shall be reduced to the plane of reference from predicted tide curves or from observed tides and significant phase or initial corrections applied when the soundings are inked on the boat sheet. Unless the soundings on the boat sheet are approximately correct, poor crossings may not be detected.

1–40 Boat sheet soundings.—Soundings shall be plotted on the boat sheet with black India ink each day as hydrography progresses. Although expert penmanship is not required, the soundings shall be of uniform size and clearly legible (see 5–63). The least depth on shoals and banks should be inked in slightly larger and heavier figures. A note and leader may be used if desired. Rock symbols shall not be obliterated by soundings or other symbols.

Bromide copies of boat sheets are used to correct nautical charts in advance of receipt of the smooth sheets. It is therefore important that the soundings and other data on the boat sheet shall not be ambiguous on these reproductions.

1–41 Depth curves on boat sheets.—The depth curves should be drawn on the boat sheet in pencil by the hydrographer and, as the work progresses, a careful study of the soundings and curves will disclose where additional development is required and where errors have been made which must be investigated. No single requirement for the spacing of depth curves can be prescribed to apply to all regions (see 5–64, 65). The curves should be spaced closely enough to depict the submarine relief completely and accurately. A good general rule is that the depth curves on boat sheets should be drawn so far as practicable at the following intervals:

(a) At 1-fathom intervals to 10 fathoms;

(b) At 5-fathom intervals between 10 and 50 fathoms;

(c) At 10-fathom intervals between 50 and 100 fathoms;

(d) At 25-fathom intervals in depths greater than 100 fathoms.

The standard depth curves required on smooth sheets should always be inked on the boat sheet in the colors prescribed for smooth sheets (Table 3). Supplementary curves may be inked if necessary to emphasize the relief.

TABLE 3.—Standard depth curves

Curve in fathoms	Curve in feet		To be inked in
0	0	(Plane of reference)	Orange.
1	6	. . . .	Green.
2	12	. . . .	Red.
3	18	. . . .	Blue.
5	30	. . . .	Red.
10	60	. . . .	Orange.
20	120	. . . .	Blue.
30	180	. . . .	Violet.
40	240	. . . .	Green.
50	300	. . . .	Red.
100	600	. . . .	Green.
200	–	. . . .	Orange.
300	–	. . . .	Violet.
400	–	. . . .	Green.
500	–	. . . .	Red.
1,000	–	. . . .	Blue.
2,000	–	. . . .	Orange.
3,000	–	. . . .	Violet.

TABLE 4.—Supplemental depth curves

½	3	. . . .	Violet.
4	24	. . . .	Orange.
6	36	. . . .	Green.
60	360	. . . .	Blue.
70	420	. . . .	Green.
80	480	. . . .	Red.
90	540	. . . .	Violet.

1–42 Bottom characteristics.—The character of the bottom shall be determined by sampling with corers, snapper cups, scoopfish, or armed leads at regular intervals. On inshore surveys the distance between samples should not exceed 2½ inches at the scale of the survey, and in depths less than 100 fathoms in offshore areas the distance should not exceed 5 inches. Between the 100 and 1,000-fathom curve, the character of the bottom shall be determined at intervals of about 5 to 10 miles. In greater depths bottom samples shall be obtained at all oceanographic stations and at such other places as the project instructions specify. In harbors and anchorages the information should be sufficiently complete to define the approximate limits of each type of bottom (see 5–76).

If the project area has been surveyed previously and bottom characteristics were adequately determined, the above spacing may be doubled unless changes in the bottom characteristics or depths are discovered. The abbreviations shown in 5–88 shall be used to record and plot bottom characteristics.

1–43 Inspection of boat sheet and records.—The Chief of Party should inspect the boat sheets and records at regular intervals, daily if possible, to assure himself that all operations are in accordance with the requirements contained in applicable manuals and the project instructions. When making his examinations, particular attention must be given to the adequacy and completeness of the survey with special reference to examination of indications of shoals, determination of least depth on submerged rocks, shoals, bars, and wrecks, and the development of navigable channels. He should determine that junctions with adjacent surveys are satisfactory and that no unsurveyed gaps are left in the area (see 5–66). After this review of the records, the Chief of Party should indicate to the hydrographer where additional work is required, and if necessary, correct any unsatisfactory methods or procedures being used.

After the survey is completed and prior to departure from the project area, the Chief of Party should make a final inspection of the sheet. All questions of adequacy or completeness of the survey should be resolved before leaving the area. The boat sheet should also be examined for clarity since it will be used in the Washington Office for preliminary revision of the chart.

1–44 Forwarding boat sheets.—Boat sheets for all surveys shall be forwarded to the Washington Office for copying as soon as practicable after the survey is completed and not later than one month after the close of a field season. The sheet should be accompanied by a tabulation of important changes found by a preliminary comparison with the largest scale chart of the area.

Where boat-smooth sheet methods are used to plot offshore hydrography, the cover sheet need not be forwarded in advance if the smooth sheet is to be completed within 3 to 4 months.

1–45 Planes of reference.—The planes of reference adopted for the reduction of soundings and the publication of charts of the Coast and Geodetic Survey are as follows:

(a) For the Atlantic Ocean and Gulf of Mexico—the mean of the low waters (MLW);

(b) For the Pacific Ocean—the mean of the lower low waters (MLLW);

(c) For certain of the larger navigable rivers and lakes special planes have been adopted. In such cases the project instructions will specify the plane of reference.

1–46 Tide stations.—If there is no primary tide station in or near the project area which will serve as a control station, a standard automatic gage shall be installed at a central point and operated during the entire period covered by the survey. As the work progresses, secondary tide stations shall be established at other places in the immediate locality being sounded. The selection of sites for the tide gages to be used in a hydrographic survey is usually made in the Washington Office and is specified in the project instructions. The number and distribution of stations will depend on the character of

the area and the change in time and range of tide from place to place. If, on arrival at the working grounds, the selected sites are found to be impracticable, the Chief of Party may make necessary subsitutions, but he must inform the Office of such changes and the reasons for them (see 2–49 to 52).

Instructions for installation, maintenance and removal of tide gages are contained in Special Publication 196, Manual of Tide Observations. When practicable, observations at each secondary station shall be continued over a period of at least 29 days. The hourly heights of the tide required for reduction of soundings shall be tabulated before the marigrams are forwarded to the Washington Office. Hourly heights from standard gage rolls will be furnished by the Office on request.

The time meridian used should be clearly marked on the first marigram. When the observations at any station are terminated, a notation of the hour and date of discontinuance should be entered on the last marigram taken from the gage. The exact location of each tide station shall be shown on hydrographic sheets (see 6–71).

1–47 Current observations.—The location of current stations will usually be indicated in project instructions. Observations at each current station shall be continuous for the number of hours specified in the instructions, except that any station at which the current fails to attain a velocity as great as 0.4 knot during the first 25 hours of observation shall be discontinued at the end of the 25-hour period.

Observations shall be taken half-hourly—on the hour and half-hour—with the current pole and Price meter, Roberts Radio Current meter, or Current Meter Recorder. All tapes should be scaled and checked promptly when taken from the chronograph or recorder. A velocity curve shall be plotted as observations progress. Instructions for current observations are contained in Special Publication No. 215.

If a vessel or current buoy is to be anchored in or near traffic lanes, adequate advance notice shall be published in local and national Notices to Mariners.

1–48 Oceanography.—Periodic measurements of temperatures and salinity are required to compute velocity corrections to echo soundings (see 5–114 to 118), except in areas where satisfactory bar checks can be obtained to the maximum depth of hydrography. The frequency of observations is a matter that must be left to the hydrographer's judgment, but it must be borne in mind that, to comply with the requirements, the average temperature from surface to bottom used to correct any sounding must be within 2 degrees of the actual mean temperature. At least one serial temperature and salinity should be observed in the deepest part of the area surveyed each month (see 3–116).

Nansen bottles and precision type reversing thermometers should be used when available and salinities determined by titration. The Sigsbee water cup with hydrometers and the Tanner-Sigsbee reversing frame and thermometer shall be used when the heavier equipment is not available.

The project instructions may require oceanographic observations in addition to the temperature and salinity observations required for reduction of soundings. Repeat observations should be made during the season to provide data on seasonal changes. The program of observations at each station shall be in accordance with instructions contained in Chapter 2, H.O. Publication 607 and outlined as follows:

(a) Nansen-bottle samples at International Nansen-bottle intervals from surface to bottom or to a maximum depth of 2,500 meters. Note that oxygen samples must be processed immediately. Chlorinity samples may be retained indefinitely.

(b) Bottom sample at all stations regardless of depth. Samples by Phleger Corer are preferred. All samples shall be retained for future analysis.

(c) Secchi disc readings.

(d) Sea and swell observations in accordance with H. O. Publication 606–e.

(e) Set and drift observations as determined by difference in position between beginning and end of observations, if practicable.

(f) Weather observations (see H.O. Publication 607, Figure C–8).

1–49 Bathythermograph (BT) Observations.—When on the working grounds or when en route to and from the working grounds, bathythermograph lowerings should be made at intervals of 2 to 4 hours. Observations should be distributed evenly and repeat observations should not be made more frequently than at intervals of 2 weeks. Data from BT slides should be tabulated and the slides preserved (see 3–115). Instructions for use of BT's are contained in H.O. Publication 607.

1–50 Aids to navigation.—All fixed aids to navigation established by the United States Coast Guard should be located by triangulation. A substitute method may be used if necessary, but the determination shall be such that no appreciable error will result. The azimuth of range lines shall be determined by triangulation if practicable.

The positions of and depths at all floating aids to navigation in the project area shall be determined by the hydrographic party. Floating aids should be located by sextant fixes, not cuts, with one or more check angles, and shall be fully described.

If a floating aid is found to be off station as shown on the largest scale chart of the area, the fact should be promptly reported to the Commander of the nearest Coast Guard District. If the aid is off station to an extent that a danger to navigation exists, the facts should be reported by dispatch. Any recommendations, based on new hydrographic surveys, for additional aids or for more desirable locations of existing aids, should be reported to the Coast Guard in writing as soon as practicable, with a photostat or tracing of the boat sheet. Copies of all correspondence with the Coast Guard shall be furnished the Washington Office (see 5–80).

1–51 Dangers to navigation.—All shoals, rocks, wrecks, etc., discovered, that are considered dangers to navigation, shall be reported immediately by radio, telegraph, or telephone to the Commander of the nearest U.S. Coast Guard District and to the Coast and Geodetic Survey District Office (see 5–72 and 7–23). A copy of the message shall be forwarded to the Washington office with a tracing from the boat sheet or chart showing the exact location of the danger.

1–52 Wire-drag investigations.—In many cases time can be saved by use of a wire drag to investigate indications of submerged dangers (see 5–124). When reported dangers or obstructions cannot be found by standard survey methods, the surrounding area should be wire dragged to prove or disprove their existence. Evidence to support a recommendation to delete charted dangers or obstructions must be conclusive. All wire-drag operations shall be conducted in accordance with the requirements of Publication No. 20–1, Wire Drag Manual.

1–53 Coast Pilot report.—All hydrographic field parties shall collect Coast Pilot information and furnish at the end of the season a special report on this subject for use in the revision of the Coast Pilot of the area (see 2–36). The report should be submitted in duplicate and should be a compilation of all such data collected by each unit of the survey party. If the information in the published Coast Pilots is correct and adequate, a statement to this effect should be included in the report.

1–54 Geographic names.—The hydrographic surveys should be the authority for all geographic names seaward from the high-water line, including the names of all water features such as channels, sloughs, rivers, inlets, bays; and those of the reefs, rocks, banks, and shoals therein; and all small islands and the names of geographic features thereon. It is particularly important that geographic names be correct not only as to name, but also as to spelling and application. Charted names and those in the Coast Pilots should be checked against local

usage. Where published names differ from local usage, the hydrographer should ascertain how well established the local name is and, if possible, the origin of it. When practicable, the field party should submit a special report on geographic names to cover the entire project area, or the portion surveyed during the season (see 7–14).

1–55 Landmarks for charts.—A report on landmarks for charts on Form 567 is required from nearly all hydrographic survey parties. Landmarks on charts are for the aid of the mariner in navigating adjacent waters and should be selected with this in mind. Where a large number of objects are available, only the most conspicuous ones should be selected for charting. An inspection should be made from the water area to determine the value of the objects reported. The report on landmarks should cover the entire area surveyed during the season. A similar report is required for charted landmarks which no longer exist or which should be deleted from the charts for other reasons. When a landmark is also used as a control station for hydrography, the word "landmark" in black ink shall be placed in parentheses below the station name (see 2–39 and 7–18, 19).

1–56 Deficiencies in surveys.—The primary purpose of a hydrographic survey is to acquire data for the publication of a nautical chart. The information must be complete and accurate. Mistakes in recorded data can usually be reconciled when the survey is smooth plotted, but omissions cannot be rectified, or inadequate data supplemented after the survey party has left the project area (see 5–75).

After a survey has been smooth plotted, it is verified and reviewed in the Washington Office. Errors in the survey and in smooth plotting are frequently discovered by the verifier (see 6–74). Adherence to instructions and standards in both phases of the operation, proper evaluation of the data, and a reasonable amount of care in smooth plotting will eliminate most of these deficiencies. The hydrographer should keep a day-to-day record of events to supplement the sounding record. Explanatory notes should be made on the boat sheet where necessary.

The following is not a complete list of deficiencies, but it does include those which cause most trouble during verification.

(a) Shoran calibrations are inadequate or have been incorrectly applied. Shoran distances have not been corrected for attenuation or passage over intervening land.

(b) Fathograms have been poorly and incompletely scanned as shown by failure to record least depths which occur at irregular intervals.

(c) Fathograms have not been correctly interpreted in areas of kelp or grass and there is a lack of supporting lead line or pole soundings in such areas.

(d) Strays have been recorded as true depths and shoal indications provided by side echoes have not been investigated.

(e) Echo sounders are carelessly operated or are in need of repair as shown by incorrect speed and lack of adjustment.

(f) Failure of agreement at crossings, or unnatural depth curves are indications that errors exist, and these indications are frequently ignored on the boat sheet and smooth sheet.

(g) The hydrographer has failed to reconcile differences between the photogrammetric manuscript and the hydrographic survey with respect to position or elevation of offshore rocks.

(h) Reducers are incorrect or are not correctly applied.

1–57 International accuracy standards for hydrographic surveys.—The American Nations, meeting in Mexico City in 1955 at the 7th Cartographic Consultation of the Pan American Institute of Geography and History, adopted accuracy standards for the conduct of hydrographic surveys. At the 7th International Hydrographic Conference in Monaco, 7–17 May 1957, the United States proposed that the International Hydrographic Bureau States Members adopt the same standards.

The standards are stated as follows:

I. Measurement of Depth:

(a) Maximum errors:
   (1) 0 to 11 fm. (0 to 20 m.): 1.0 ft. (0.3 m.);
   (2) 11 to 55 fm. (20 to 100 m.): 0.5 fm. (1.0 m.);
   (3) 55 fm. (100 m.) and deeper: one per cent of depth.

II. Scale of Survey:
   (a) In general, never less than that of the published chart and preferably:
      (1) For rivers, lakes, harbors, channels, and pilot waters:
         —Multiples of 1/1000 for scales to 1/10000
         —Multiples of 1/2500 for scales from 1/10000 to 1/20000
      (2) For coasts and oceans:
         —Depths generally less than 30 fm. (60 m.): 1/40000 or larger;
         —Depths generally less than 100 fm. (200 m.): 1/100000 or larger;
         —Depths generally greater than 100 fm. (200 m.): 1/250000 or larger.

III. Interval of Sounding Lines:
   (a) Spacing of principal lines: 0.4 in. (1.0 cm.) or less, except where depth and character of the bottom will permit wider spacing;
   (b) Spacing of cross (check) lines: 3.0 in. (7.5 cm.) or less.

IV. Interval of Plotted Soundings:
   (a) Frequency along sounding lines: 0.2 in. (0.5 cm.) or less.

V. Sampling of Bottom Characteristics:
   (a) In general sufficient sampling to demarcate the limits where one general type of bottom changes to another. Samples in depths less than 30 fathoms (60 m.) should be obtained at a spacing of 3 inches (8 cm.) or less at the scale of the survey sheet, depending on type of bottom. Beyond that depth special equipment is required; therefore, bottom samples shall be obtained only when conducting oceanographic observations of the area. When surveying deep anchorage areas, depth should be extended beyond 30 fathoms in order to determine character of holding ground.

VI. Position Fixes:
   (a) Spacing on survey sheets: 1 to 1.5 in. (2 to 4 cm.);
   (b) Maximum error of plotted position (relative to a shore control): 0.05 in. (1.5 mm.);
   (c) Location of shore control: from a triangulation scheme of 3rd-order accuracy or better.

VII. Reference of Sounding to Vertical Datum:
   (a) Location and duration of water stage observations to be such that each sounding can be referenced to the selected vertical datum with an error no greater than one-half that specified for measurement of depth.

2. PLANS AND PREPARATIONS

2–1 Purpose of a hydrographic survey.—The principal object of all hydrographic surveying by the Coast and Geodetic Survey is to obtain information concerning the water areas and adjacent coast for the compilation of nautical charts, coast pilots and related publications. Hydrography is defined as that branch of surveying which embraces the determination of the configuration and composition of the bottom of the ocean, a harbor or other body of water; the depth of the water; and the position of channels and shoals. A hydrographic survey party is generally required to perform a variety of other survey operations which may include: astronomic observations, triangulation, topographic surveys, and magnetic surveys. Therefore, the activities of a hydrographic party are termed "combined operations."

2–2 Survey manuals.—This manual is one of a series of Coast and Geodetic Survey manuals and publications designed to describe the methods and equipment used and to state the requirements for various survey operations. Since this manual deals primarily with hydrographic methods only, the combined operations party needs continually at hand several manuals covering other phases of the work. Depending on the nature of the project, the following should be available:

Special Pub. No.	*Title*
5	Tables of Polyconic Projections.
Ser. 166	Directions for Magnetic Measurements.
20–1	Wire Drag Manual.
239	Manual of Geodetic Leveling.
8	Formulas and Tables for the Computation of Geodetic Positions.
247	Manual of Geodetic Triangulation.
196	Manual of Tide Observations.
215	Manual of Current Observations.
249	Topographic Manual—Part II.
256A	EPI Manual.
H.O. 226	Handbook of Magnetic Compass Adjustment and Compensation.
H.O. 607	Instruction Manual for Oceanographic Observations.
H.O. 614	Processing Oceanographic Data.
25–1	Coast Pilot Manual.

In addition to the numbered publications listed above, the survey party should have service manuals for equipment being used, as: echo sounders, Shoran, Raydist, etc.

2–3 Project defined.—The field operations of a survey party in a specified area are considered a project and each project is assigned a number, as CS–406, the letters being the abbreviation for Coastal Surveys. All correspondence and reports relating to the project should include reference to the project number.

Field examinations and surveys of very limited extent are called special surveys, for purposes of record, and are not assigned project numbers. They are identified thus: Special Survey 4–58, indicating the 4th special survey in 1958.

Surveys accomplished at the request of other agencies and financed by the requesting agency are assigned numbers which reflect the cost accounting symbol assigned to reimbursable projects.

Each combined operations project is developed on the basis of requirement for a specific chart or as part of a long-range charting program.

2–4 Project instructions.—Instructions are written for each project to supplement the published manuals. The details of the instructions vary from specific to general depending on the locality and nature of the survey. The Chief of Party shall suggest changes in specific instructions when, in his opinion, such amendments should be made in the interest of safety of personnel or property, for reasons of real economy, or on the basis of valid engineering principles. Ordi-

narily the project instructions will be divided into and treat of the following subjects: general, control, photogrammetry or topography, hydrography, tides, currents, oceanography, magnetics, and miscellaneous. A copy of a chart of the area will be furnished on which are shown: project limits, limits of prior surveys, and proposed current, magnetic, and oceanographic stations.

2–5 General instructions.—In the general part of the instructions the limits of the areas to be surveyed are specified, and prior surveys with which junctions are required are listed. A plan of operation will be stated indicating the area in which operations are to begin and the desired direction of progress. When two or more chiefs of party are assigned to operate in the same area on the same project, their respective areas of operation and division of authority are defined.

2–6 Instructions for geodetic control.—Copies of triangulation diagrams, lists of geographic positions and descriptions of triangulation stations will be furnished for the project area. An index of control will also be furnished when available. The project instructions will ordinarily state whether new triangulation is necessary, and, if so, the requirements as to junctions and order of accuracy.

2–7 Instructions for photogrammetric and topographic surveys.—Blackline impressions, blueline tracings, and paper prints of photogrammetric manuscripts, together with field and office copies of photographs, will be furnished for most projects. Each manuscript will be classified as preliminary, incomplete, or advance (see 4–12). The instructions will state requirements, if any, for identification of horizontal or vertical control and will specify areas where field inspection is necessary. Photogrammetric methods should be used for location of signals wherever practicable (see 4–18). Ground survey methods shall be used to supplement the photogrammetry where necessary or expedient.

Instructions will state which areas are to be surveyed by planetable methods and copies of the most recent topographic surveys of such areas will be furnished for revision as necessary. All planetable surveys shall be made on aluminum-mounted sheets, unless otherwise specified, and in accordance with instructions contained in Topographic Manual (Special Pub. No. 144). (See 4–20).

2–8 Instructions for hydrography.—A presurvey review compiled by the Chart Division will usually be furnished on a large scale chart of the project area. Charted features which require investigation will be indicated (see 6–108). The presurvey review does not relieve the Chief of Party from his responsibility to compare surveys with charted data. Copies of the most recent hydrographic surveys in the project area will be furnished for comparison or junction purposes.

The instructions for hydrography will ordinarily specify:

(a) The scales to be used. The Chief of Party is authorized to use larger scales in small harbors if he so desires.

(b) Maximum spacing of sounding lines referred to certain areas or depths.

(c) The percentage of crosslines to be run.

(d) The required frequency of bottom samples.

(e) Sounding and positioning equipment to be used.

(f) Project limits and junctions to be made.

(g) Wire drag investigations required.

2–9 Instructions for tide stations.—Copies of the reports of tide stations previously established in the area, with the elevations and descriptions of bench marks and the heights of the datum planes at each, will be furnished. The instructions will specify what tide station is to be used as a standard reference station for the project. An inspection of, and report on, an existing station may be required. Supplemental tide stations are usually required and the instructions will usually specify how many are necessary and the desired locations. A Chief of Party is authorized to depart from a specified location if, on examination, it appears impracticable (see 1–46).

All tide stations shall be established in accordance with the instructions contained in Special Publication No. 196, Manual of Tide Observations, except as amended by project instructions.

2–10 Instructions for current stations.—When current observations are to be made, the project instructions will specify: (a) where they are to be made, (b) the period of continuous observations required at each station, and (c) the instruments to be used in obtaining the data.

Current observations shall be made in accordance with instructions contained in Special Publication No. 215, Manual of Current Observations (1950 edition) except as amended by the project instructions (see 1–47).

2–11 Magnetic observations.—The project instructions may specify locations where magnetic stations are required. In the absence of specific instructions, magnetic observations should be made with a transit magnetometer at intervals of 5 to 10 miles along the coast. The instrument used should be standardized before and after the field season by making four complete sets of declination at a standard station. Magnetic anomalies of 2° or more should be investigated to determine their limits. Observations shall be made in accordance with instructions contained in Serial No. 166, Instructions for Magnetic Measurements.

2–12 Oceanographic observations.—When oceanographic observations are to be made in addition to temperature and salinity determinations required for correction of echo soundings, the project instructions will specify: (a) station locations, (b) frequency of repeat observations, (c) types of observations to be made, and (d) instruments to be used. Observations shall be made in accordance with instructions contained in Hydrographic Office Publication No. 607, Instruction Manual for Oceanographic Observations, except as modified by the project instructions (see 1–48).

2–13 Miscellaneous instructions.—The miscellaneous instructions will specify the scale of the chart to be used in drafting the progress sketch to be submitted each month, and will usually call attention to general requirements for coast pilot notes, chart inspections reports, and procedures to be followed if new dangers to navigation are discovered.

The Chief of Party shall acknowledge receipt of project instructions, and amendments thereto, in writing.

2–14 Project study.—On receipt of project instructions and the accompanying data, the Chief of Party should make a careful study of them to assure himself that all necessary data have been received. If omissions are discovered, or the data forwarded are considered insufficient, he should request from the Washington Office any additional data required. He should also report to the Washington Office immediately any revisions of the requirements which he recommends, any parts of the instructions which are not clearly understood, or any subjects relative to the project about which he desires more complete or additional information.

2–15 Plan of operation.—The project instructions may call for priority in certain phases of the operations and these must be planned for completion in the order of precedence established. In the absence of priorities, the work should be planned to provide uniform and parallel progress of the various operations. In order to plan and carry out effectively and systematically extensive combined operations, it will generally be necessary to plot on a chart of suitable scale the limits of the project, the limits of previously surveyed areas with which junctions must be made, all previously established triangulation stations in the area, and any other data which may be used in developing the plan. A division of operations between the various units of the party should be made so as to secure maximum progress consistent with economy and safety in the use of the survey ship and launches.

Obviously any general plan of operations is subject to change as field work progresses.

However, there is a sequence of events which is fundamental to successful operation.

First, the adequacy of the established triangulation should be evaluated and a preliminary reconnaissance should be made if additional control is required. If photogrammetric methods are to be employed for locating hydrographic stations, the character of the photogrammetric coverage should be studied and plans laid for this part of the work which will assure the availability of advance or final manuscripts when they are needed for hydrography. Whether signals are to be located by planetable or photogrammetrically, they should be built and located sufficiently in advance of the hydrographic party to avoid delays. It is not advisable to build signals in excess of those needed during the season.

Nearly all shoreline and topographic mapping is accomplished by photogrammetric methods. Preliminary manuscripts can be compiled from photographs without prior identification of control or shoreline inspection (see 4–13). This procedure is inefficient and should be avoided since preliminary manuscripts must be recompiled and signals relocated after control has been identified. When photographs are available, field inspection and control identification should be completed one year in advance of hydrographic operations. If there is no established control in the area, or if supplemental control is required, the triangulation surveys and photogrammetric work should be carried on simultaneously.

2–16 Aerial photographs for operational planning.—Aerial photography and topographic, or planimetric, mapping will usually precede hydrography. Copies of the maps and photographs will be furnished as part of the project data. At times the photographs may be available ahead of the planimetric or topographic maps. In the absence of detailed maps, the photographs will provide a wealth of information for planning operations, and, even when the maps are immediately available, the photographs will provide additional information useful in operational planning.

The aerial photographs for a project may be either nine-lens or single-lens vertical photographs. Nine-lens photographs will have been taken at the anticipated scale of the inshore hydrography and, once taken, the scale of these photographs is fixed; it is not practicable to furnish prints at larger or smaller scales. Single-lens photographs will usually be taken at some scale smaller than the anticipated scale of the inshore hydrography. Ratio prints at the latter scale will be used for map compilation and will be furnished the hydrographic party. When single-lens photographs are used, ratio prints can be furnished in the range of one-half to four times the contact or taking scale.

The Bureau is making increasing use of infra-red and color photography to supplement the panchromatic mapping photography. This special purpose photography is used in compilation of the topographic or planimetric maps that usually precede hydrography, and the special photography can be made available to the hydrographic party, if needed. Infra-red photography increases the contrast between land and water and emphasizes the shoreline. When infra-red photography is taken at the proper stage of the tide, that is, for example, at low tide or at high tide, it defines the low water line or the high water line very sharply. These photographs show clearly which features, as, for example, rocks, are bare at the stage of the tide at which they were taken. Infra-red photography also reduces sun spots that occasionally obscure some of the shoreline on panchromatic photography. Color photography has greater depth penetration than panchromatic photography, and is useful in outlining shoals and channel lines that must be developed by the hydrographer.

Some information can be obtained from a casual examination of the aerial photographs, but a stereoscopic examination is essential if optimum information is to be obtained from them. Nine-lens photographs, or larger ratio prints of single-lens photographs, are somewhat of a problem when using the smaller stereoscopes available in the field. For this reason the photographs should be cut and folded for convenient view-

ing (refer to Photogrammetry Instructions 43).

The following is a partial summary of the types of information available for operational planning from a stereoscopic study of aerial photographs:

(a) In unsurveyed or poorly surveyed areas, the approaches to the coast and routes along it both for the ship and small boats; whether there are off-lying islands, rocks, reefs, or shoals, and the probable clear channels between them; protected areas possibly suitable for anchorage, and the best landing places for small boats.

(b) The roads, trails, settlements, etc.; special means of transport and supply other than by water, which may be desirable; whether the terrain is bare or wooded; the relief, landmarks, etc.

(c) Suitable sites for triangulation stations as well as the clearance of lines between those stations, and sites for signals to control offshore hydrography. The use of photographs in connection with triangulation reconnaissance is discussed in detail in 4–8.

(d) The nature of the shoreline and the foreshore and the types of objects that will be available for hydrographic signals.

(e) Shoals, reefs, foul areas, and channels are often visible to a degree and usually a considerable amount of information about these can be transferred from the photographs to boat sheets to assist the hydrographer.

In summary, the aerial photographs permit an advance reconnaissance of the area. Such a reconnaissance is desirable prior to arrival on the working grounds and notes should be made freely from it. Usually these notes can be placed directly on the photographs. After arrival on the working grounds, the notes made during the advance reconnaissance study will facilitate the detailed study of the photographs for planning day-to-day operations. This type of study is of particular importance for original hydrographic surveys in remote areas.

2–17 Inspection of survey equipment.—It is customary to overhaul and service all survey instruments and equipment at the end of each field season. Instruments in need of repair are sent to the Washington Office and replacements requested. After receipt of project instructions, the instrument inventory should be reviewed and additional instruments requisitioned from the Washington Office as necessary. Last-minute requests just before the start of a field season should be avoided.

2–18 Training of personnel.—Each of the survey operations requires a maximum of experienced personnel in order that accurate and reliable results may be obtained. At the beginning of a season the survey party will ordinarily have some members who have had little or no experience in survey work. A few days of instruction, explanation, and practice in calm waters of the base harbor should prove profitable. When engaged in repetitious work such as launch hydrography, each member of the party should be trained to do any of the various operations involved (see 5–57). This practice will relieve the monotony and strain of some phases of the work, foster a greater interest in the whole operation, and provide trained personnel for assignment to vacancies in an emergency.

The efficiency of a survey party and the quality and quantity of results obtained will depend largely on the experience and qualifications of the officers and men and the interest and pride they take in their work. Assignments should be based on the experience and general aptitude of each individual, and the degree of reliability that can be placed in his work. One of the functions of a Chief of Party and of an officer in charge of a subparty is to encourage the personnel under his direction to learn their duties and become proficient in their work, and to provide them with opportunity for obtaining the all-around experience necessary to enable them to assume charge of similar operations when called upon to do so. Junior officers, in particular, should be trained in all possible phases of combined operations even though there may seem to be some loss of efficiency by doing so.

2–19 Survey scales.—The basic scale for hydrographic surveys of the Coast and Geodetic Survey is 1:20,000, and almost all other scales bear a simple relationship to it. No inshore survey adjacent to the coast shall be on a scale smaller than 1:20,000, except by authority of the Director. In inshore areas, surveys at 1:25,000 will sometimes result in a better sheet layout without the use of oversize sheets and still permit adequate development of the bottom features. Before reducing the scale of the field survey, consideration should be given to making the survey on an oversize sheet and then reducing the size of the smooth sheet by smooth-plotting the survey at a smaller scale (see 6–7). The latter practice is preferable from the view of the chart compiler. In either case, prior approval must be obtained.

Scales smaller than 1:20,000 shall generally be those whose denominators are multiples of 20,000 (i.e., 1:40,000, 1:60,000, 1:80,000, etc.) except that surveys at 1:30,000 or 1:50,000 are authorized where the use of these scales in place of the 1:40,000 scale will result in better sheet layout without the use of oversize sheets, and/or better development of bottom features.

Larger scales shall be multiples of 1:20,000, each scale being double that of the preceding scale (i.e., 1:10,000, 1:5,000, and 1:2,500). All important harbors, anchorages, channels, and many parts of the coast where dangers are numerous or piloting is difficult, shall be plotted on scales of 1:10,000 or larger.

The choice of scale is obviously dictated by the amount of detail required on the hydrographic sheet. A Chief of Party is authorized to use, at his discretion, scales larger than those required by project instructions. The scale selected for the smooth sheet must never be smaller than—and preferably twice as large as—that of the largest-scale published chart of the area (see 1–6).

Offshore surveys controlled by Electronic Position Indicator should not be plotted at scales larger than 1:100,000. When Raydist equipment is used a scale should be selected which will permit use of a line spacing adequate for the area.

2–20 Sheet Layout.—Since boatsheets of different scales will be required for surveys of different parts of a project area, it is essential that a sheet layout be constructed as part of the preliminary planning. In order that these sheets may be planned practicably and economically, a sheet layout should be made on a chart of appropriate scale. A tracing of the sheet layout should be forwarded to the Washington Office for record and approval before the boat sheets are made (see 1–7).

Each hydrographic sheet should be laid out in such a manner that it will include as large a water area as practicable, at the same time providing for adequate overlap with adjacent sheets and ensuring that the survey can be adequately controlled. The overlap of adjacent sheets should be sufficient to provide for a suitable junction with adjacent surveys and to include the necessary control. As a result of handling and age some smooth sheets tend to crack along the edges, and soundings near the edge may become illegible. For this reason, it is desirable to lay out the sheets so that it will not be necessary to plot soundings closer than three inches to the edge of a sheet.

A convenient method for making this layout is to construct on tracing cloth or clear plastic one or more models of each standard size sheet according to the scale of the chart on which the layout is to be made. The models may then be shifted about on the chart, giving consideration to required overlap, until the best position for each sheet is determined. Where the area is complex it is frequently necessary to try various layouts of sheets before the most practicable and economical one is found. As the best position for each sheet is determined, the four corners may be pricked through to the chart and joined by straight lines on the layout (see Fig. 2).

The area that will be included on a sheet of given dimensions at a specified scale may be readily determined from Table 5 by mul-

TABLE 5.—Scale equivalents for laying out survey sheets

Scale	One inch equals		One centimeter equals		One nautical mile equals		One statute mile equals	
	Nautical miles	Statute miles	Nautical miles	Statute miles	Inches	Centi-meters	Inches	Centi-meters
1:2,500	0.034	0.039	0.013	0.016	29.165	74.08	25.344	64.37
1:5,000	.069	.079	.027	.031	14.582	37.04	12.672	32.19
1:10,000	.137	.158	.054	.062	7.291	18.52	6.336	16.09
1:20,000	.274	.316	.108	.124	3.646	9.26	3.168	8.05
1:30,000	.411	.473	.162	.186	2.430	6.17	2.112	5.36
1:40,000	.549	.631	.216	.249	1.823	4.63	1.584	4.02
1:50,000	.686	.789	.270	.311	1.458	3.70	1.267	3.22
1:60,000	.823	.947	.324	.373	1.215	3.09	1.056	2.68
1:80,000	1.097	1.263	.432	.497	.911	2.31	.792	2.01
1:100,000	1.372	1.578	.540	.621	.729	1.85	.634	1.61
1:120,000	1.646	1.894	.648	.746	.608	1.54	.528	1.34
1:200,000	2.743	3.157	1.080	1.243	.365	.93	.317	.80
1:400,000	5.486	6.313	2.160	2.486	.182	.46	.158	.40
1:500,000	6.858	7.892	2.700	3.107	.146	.37	.127	.32
1:1,000,000	13.715	15.783	5.400	6.214	.073	.19	.063	.16

1 Nautical mile = 6,076.10 ft. or 1852.0 m.
1 Statute mile = 5,280 ft., or 1609.3 m.

tiplying the dimensions of the sheet by the number of miles at the selected scale. For example, a sheet 36 by 54 inches on a scale of 1:20,000 will include an area 9.8 by 14.8 nautical miles.

If planetable topographic or graphic control surveys are required, the location of the sheets should be shown in the sheet layout.

2–21 Sheet orientation.—All hydrographic sheets shall be laid out so that the projection lines are approximately parallel with the sides of the sheet, except when such a layout is extremely uneconomic or impracticable. The reason for this is that a cloth-mounted sheet distorts almost uniformly along its axes and if the sheet is laid out with the projection lines parallel to the edges, distortion is comparatively easy to compensate for in chart compilation. With a skewed projection it is much more troublesome and, in addition, such a sheet is inconvenient to handle. North shall always be considered the top of the sheet, whether or not the projection lines are parallel to the edges of the sheet.

2–22 Sheet sizes.—The standard size for all hydrographic sheets shall be 36 by 54 inches and they shall ordinarily not exceed this size (see 1–8 and 6–3). Chiefs of Party are authorized to increase the sheet size to 36 by 60 inches in exceptional cases, but approval must be obtained from the Director before using a sheet larger than 36 by 60 inches. Flat sheets 36 by 60 or 42 by 60 inches will be furnished on requisition to the Washington Office and shall be used for boat sheets and smooth sheets. Use of other types of paper for this purpose is not authorized. The 42-inch width may be used when considerations of control make it advisable; however, hydrography should be limited to an area 30 inches wide in order that the sheet may be trimmed after verification and review.

Calibration sheets should be constructed on grained aluminum or aluminum-mounted paper sheets which can be furnished in various thicknesses and sizes as large as 38 by 59 inches. Drawing paper mounted on aluminum sheets or foil is the most satisfactory solution to the distortion problem if the sheets are not unduly exposed to moisture. The paper must be mounted on both sides of the aluminum, otherwise the paper will contract or expand, and warp the sheet.

Unless otherwise instructed, all planetable topographic or graphic control surveys shall

be done on aluminum-mounted sheets. The size used is 24 by 31 inches, which is identical with the size of the planetable board.

2–23 **Subplans.**—Sheets containing small detached areas of hydrography shall be avoided, if practicable. This can usually be accomplished by placing a subplan, or inset, on the boat and smooth sheets at the same or an enlarged scale (see 6–6). If it is impracticable to include, in the original sheet layout, an entire area on several standard-sized sheets, and a small section remains that is necessary for effecting a junction with a prior survey, it is frequently practicable to include such area as a subplan on an unused portion of the adjacent sheet. Such subplans must always be included on the sheet of comparable scale closest to the area.

Where a small harbor, anchorage, or other area needs to be surveyed at a larger scale than the remainder of the inshore coastal waters, it likewise may frequently be included as a subplan on the sheet which includes the area.

It is to be noted that the boat sheets are not necessarily similar in layout to the smooth sheets and there is no objection, and in many cases there is a decided advantage, in surveying the area on separate boat sheets. The results of several small boat sheets may be included on one smooth sheet.

2–24 **Dog-ears.**—It is sometimes impracticable to determine in advance the exact limits of a hydrographic sheet. Because of developments during progress of a survey or the location of control, it is occasionally desirable or necessary to use a control station which falls a short distance beyond the limits of the sheet as originally laid out. This is accomplished by adding a small section of paper, called a "dog-ear," to the boat sheet and plotting the station thereon. While there is no objection to the use of dog-ears on boat sheets, there is serious objection to their use on smooth sheets, and they are not to be tolerated on the latter except in emergency (see 6–5).

2–25 **Shore party operations.**—It is frequently more efficient to assign a portion of the work, especially triangulation and topography, to one or more shore parties operating independently but responsible to the Chief of Party. In well-developed areas these parties can generally use trucks for transportation during progress of the work and for changing base of operations. Photogrammetrists are usually assigned to assist hydrographic parties in the United States, and are self-sufficient. The party will usually have an office-trailer, one or two trucks, and a small boat which can be launched from a trailer when needed.

Where launch hydrographic surveys, or other operations requiring the use of boats, are made by a party based ashore, the camp sites or anchorages must be chosen so that time required for runs to and from the working ground will be at a minimum, and at the same time provide safe anchorage for the floating equipment.

When electronic distance measuring equipment is used to control hydrography, it will be necessary to establish a small unit at each shore station. Since all shore-based units must be supplied at regular intervals, the locations selected should be such that landings can be made under all conditions of sea and weather, if possible.

2–26 **Radio communications with detached units.**—Most launches, and shore parties operating from a ship, will be equipped with radiophones and will be in communication with the Chief of Party at regular intervals. The Radio Regulations of the International Telecommunications Conference are very specific with respect to procedures to be employed when radiophones are used. The Chief Electronics Technician, or other responsible person on each party, shall train all users of radio communications equipment in order that infractions of the regulations will be avoided. Copies of the regulations are furnished without request as they are issued.

2–27 **Weather.**—Few operations in a hydrographic survey can be conducted with efficiency and accuracy during periods of stormy weather and much of the work re-

quires exceptionally good weather. The Chief of Party should make a study of the meteorological conditions of the project area. In most areas there will be periods best suited to certain operations which require good visibility. Such periods often follow a storm when clear weather will prevail for a few days. In some localities there is a dependable cycle of weather conditions during which a period of calm or clear weather can be predicted. Much valuable information on weather observations, weather forecasts, and cyclonic storms will be found in Chapters 37, 38, and 39 of H.O. Pub. No. 9, American Practical Navigator (Bowditch 1958).

2–28 **Compass deviations.**—For accuracy of hydrographic surveys and the safety of the survey vessel it is essential that the errors of the magnetic compasses be kept to a minimum and that their amounts be known. Each survey ship and auxiliary vessel equipped with a magnetic compass shall be swung to determine the compass error, which shall be compensated for, so far as practicable, at the following times:

(a) After any extensive lay-up period in port, before proceeding to sea.

(b) On the working ground at the beginning of each season's work.

(c) During the field season whenever there is evidence of an important change in the deviations.

The above rules apply even though the vessel may also be equipped with a gyrocompass. A compass log shall be kept in which should be entered:

(a) Dates when the vessel is swung, record of compass adjustments made, and table of deviations.

(b) Record of azimuths observed.

(c) Compass comparisons observed (at least once each watch).

Instructions for swinging ship and compensating compasses are contained in H.O. Publication No. 226, Handbook of Magnetic Compass Adjustment and Compensations. The results of the ship swing and computations of deviations are recorded in Forms 354, 355, and 356.

The deviations of a magnetic compass *used in hydrographic surveying* shall be entered on Page 1 of the first volume of the sounding records of each hydrographic survey, and, if changed during the survey, the new values shall be entered in the appropriate volume, with the date of their applicability given. Deviation tables are not required for boat compasses, or when a gyrocompass is used in hydrographic surveying.

A deviation table on Form 261, containing the most recent values, shall be posted in the pilothouse or chartroom of every survey vessel.

2–29 **Navigation and seamanship.**—The operation of sounding from a vessel, and the various other operations performed by a survey vessel underway, requires navigation of the highest order and expert ship handling. Many of the conditions which are encountered almost daily by the hydrographer are met by the average mariner only in emergencies. A knowledge of how to navigate and handle his vessel under all conditions and of the proper use of lines and anchoring gear is essential to the hydrographer. Launches and other boats are used almost daily and it is frequently necessary to retrieve them under adverse conditions. Every officer engaged in hydrographic surveying should endeavor to perfect himself in the theory and practice of navigation. The Commanding officer should provide reasonable opportunity for officers and men to become proficient in all phases of the operation. Each officer's training and experience should eventually qualify him for command.

2–30 **Safety of survey ship.**—The Commanding Officer of a survey ship has a grave responsibility; he is personally responsible for the lives and safety of his officers and crew and for the safety of an expensive survey ship.

The nature of hydrographic surveying requires that more risk be taken at times than would be necessary in commercial navigation; this is especially true when operating in an unknown or previously unsurveyed area. To prosecute such work expeditiously it is necessary to run some risks that would other-

wise be considered fool-hardy. In such cases the Commanding Officer must exercise the nicest discrimination, but both he and his officers must beware of overconfidence.

In surveying an area where a known danger exists, or where one has been reported or is suspected of existing, certain definite precautions are necessary. Because of the wide variety of conditions which may be encountered, no all-inclusive rules of safety can be drawn. The following general rules should be followed when approaching a known or suspected danger:

(a) If practicable, the dangerous area shall first be surveyed from a launch to find and locate the danger and to survey an area around it with which a junction can be made in safety from the survey ship.

(b) The Commanding Officer, before approaching the area, shall make a study of all available data.

(c) The Commanding Officer shall be on the bridge, and shall take charge of the navigation of the ship.

(d) The ship shall proceed at slow speed.

(e) An officer shall be on the lookout in addition to any members of the crew.

(f) Information on reported dangers may be incorrect as to location, depth, and number of submerged obstacles.

2–31 International code flags.—A complete set of International Code flags shall be carried for navigational purposes, being displayed as the occasions require.

A card illustrating the various flags shall be kept in the pilothouse in a convenient location.

Ships and auxiliary vessels engaged in hydrographic surveying underway in the daytime should display suitable International Code signals in areas where there may be considerable foreign ship traffic. The appropriate International Code signals are:

> "HD," Signifying "I am engaged in submarine work, you should keep clear of me."
>
> "HF," Signifying "I (We) have a sweep out, you should keep clear of it."

In addition to the above signals, the code flags most frequently used by ships of the Coast and Geodetic Survey are the red flag to indicate that explosives or highly inflammable fuels are being loaded, and those composed of groups used in recalling launch and shore parties.

2–32 Inland and international rules.—The Inland and International Rules of the Road authorize or require a survey vessel to display prescribed recognition signals. The lights or shapes shall be displayed in accordance with the rules as follows:

(a) **Section 80.33 Pilot Rules for Inland Waters.**—By day a surveying vessel of the Coast and Geodetic Survey, under way and employed in hydrographic surveying, may carry in a vertical line, one over the other not less than 6 feet apart where they can best be seen, three shapes not less than 2 feet in diameter of which the highest and lowest shall be globular in shape and green in color and the middle one diamond in shape and white.

Vessels of the Coast and Geodetic Survey shall carry the above-prescribed marks while actually engaged in hydrographic surveying and under way, including drag work. Launches and other boats shall carry the prescribed marks when necessary.

It must be distinctly understood that these special signals serve only to indicate the nature of the work upon which the vessel is engaged and in no way give the surveying vessel the right-of-way over other vessels or obviate the necessity for a strict observance of the rules for preventing collisions.

By night a surveying vessel of the Coast and Geodetic Survey, under way and employed in hydrographic surveying, shall carry the regular lights prescribed by the rules of the road.

A vessel of the Coast and Geodetic Survey, when at anchor in a fairway on surveying operations, shall display from the mast during the daytime two black balls in a vertical line and 6 feet apart. At night two red lights shall be displayed in the same manner. In the case of a small vessel the distance between the balls and between the lights may be reduced to three feet if necessary.

Such vessels, when at anchor in a fairway

on surveying operations, shall have at hand and show, if necessary in order to attract attention, a flare-up light in addition to the lights which are, by this section, required to be carried.

(b) International Rules of the Road.—A vessel engaged in surveying or underwater operations when from the nature of her work she is unable to get out of the way of approaching vessels, shall carry in lieu of the white range or masthead lights, three lights in a vertical line, one over the other, not less than 6 feet apart. The highest and lowest of these lights shall be red, and the middle light shall be white, and they shall be of such a character as to be visible all round the horizon at a distance of at least 2 miles. By day, she shall carry in a vertical line one over the other and not less than 6 feet apart, where they can best be seen, three shapes each not less than two feet in diameter, of which the highest and lowest shall be globular in shape and red in color, and the middle one diamond in shape and white.

These signals indicate that the vessel is not under command, and cannot get out of the way of approaching vessels. When it is apparent that an approaching vessel does not heed the signals displayed by the survey vessel, the danger signal should be sounded by the survey vessel.

A vessel engaged in surveying or under water operations, when at anchor, shall carry the lights or shapes prescribed above in addition to the anchor lights or shape required by the rules.

A survey vessel underway on a sounding line at night shall show the lights, prescribed for a vessel of her size; and when at anchor and not engaged in survey operations shall show only the anchor lights or shape prescribed for a vessel of her size.

2–33 Small-boat landings.—There is perhaps no one phase of seamanship so essential in hydrographic surveying as competency in handling small boats and making landings on exposed coasts. Most hydrographic surveys consist of operations along the coastal area where the sea meets the shore, and where the greatest danger lies. The very nature of the operations requires the use of small boats and repeated landings on the shore. An important feature of the training of new members of a crew at the beginning of each field season is to familiarize them with these duties and to provide every opportunity for them to acquire practice.

Officers and a crew who are experienced lifeboatmen and seamen are essential in hydrographic surveying, but it must not be assumed that one who is an otherwise competent seaman has the knowledge and experience required to make small-boat landings under dangerous conditions. This is an art in itself, requiring a special knowledge and skill only acquired by practical experience and which many seafaring men never have occasion to practice. When undertaken by the inexperienced, the danger involved can scarcely be overestimated.

The subject is adequately treated, insofar as practicable in text, in many treatises on seamanship, and these should be studied thoroughly and reviewed at the start of each field season. The rules published by the Royal National Lifeboat Institution on the subject are very helpful. An almost infinite variety of conditions may be encountered, and the method adopted must vary to meet them successfully. This Manual can only emphasize the importance of the following in connection with small-boat landings under difficult conditions:

- Use only experienced personnel.
- Conditions never appear as dangerous from seaward as they really are.
- Always use a steering oar, never a rudder.
- Keep the boat under control at all times.
- The outermost of a series of breakers is much the heaviest.
- In a strange locality, lie-to outside the breakers to study the particular conditions before attempting a landing.
- The one great danger, when running before a broken sea, is that of broaching-to.
- A number of heavy swells are often followed by a short and comparatively mild interval.

Launching a boat through breakers is a more difficult and exhausting operation, though not necessarily a more dangerous one, than making a landing under similar conditions.

An entirely different technique is required on a steep rocky shore from that required on a gently sloping sand beach.

2–34 Leases of station sites.—When electronic equipment is to be used for control of hydrography, suitable locations for establishing shore stations should be selected and station marks located prior to beginning the field season. It may be necessary to lease private property for this purpose. Such leases should be executed and cleared through the Washington Office well in advance of establishment of the station. If the station is to be located on Federally-owned land, use permits should be obtained and forwarded to the office.

The area required for each station will vary with the type of equipment used. A portable Raydist station, or Shoran station with a short mast, can be set up on a lot as small as 50 feet square; but a Raydist complex of towers will require a space approximately 800 by 300 feet. The site should be clear and approximately level.

2–35 Selection of station sites.—There are several factors which should be considered when selecting a site for establishment of shore stations for electronic control:

(a) Adequacy of coverage for the area to be surveyed. The stations should be located so as to provide strong intersections of distance arcs. Approximate limits of adequate service can be defined as: maximum distance offshore equal to twice the length of the baseline (distance between stations), and the closest approach to the center of the base line equal to one-fourth of the baseline.

(b) The station should be at, or near, a triangulation station. If this is not possible, the mast should be visible from two or three triangulation stations nearby (see 1–19).

(c) The site should be selected so that there will be little or no land intervening between the stations and the service area, and, in the case of Raydist, there should be little land between the stations.

(d) The availability of commercial sources of power is desirable but not essential.

(e) Problems of housing and supplying personnel at the station.

(f) If Shoran is to be used, the station must be sufficiently elevated to provide line-of-sight coverage for the maximum distance required. It should not be so high that distance corrections are required for inshore surveys.

(g) Operation of the equipment should not interfere with, or be affected by, other electronic or radio facilities in the area.

2–36 Coast Pilot reports.—The Coast Pilots of the Coast and Geodetic Survey are a series of volumes containing information of importance to the navigator which cannot be shown conveniently on nautical charts and is not readily available elsewhere. A new edition of a pilot is published at intervals which may vary from 5 to 12 years. Supplements to each Pilot are published annually and contain corrections, changes and new information. Each supplement is complete for the period between the date of publication of the Pilot and the date of the supplement.

Coast Pilot reports from field parties are among the most important sources of information. All hydrographic parties shall collect Coast Pilot data and furnish at the end of each season a special report on this subject (see 1–53). This report should include information obtained while en route to and from the project area as well as that gathered on the working ground. A mere revision of the published text of the Pilot is not all that is required, but additional new information should be obtained that will enhance its value.

The report should be submitted in duplicate, the information to be contained therein and the manner in which it should be furnished being described in the Coast Pilot Manual. Such data should not be made a part of the descriptive reports.

Important information and especially anything affecting the safety of navigation

should be forwarded to the Washington Office at once. All dangers to navigation discovered shall be reported to the Commander of the Coast Guard District by dispatch and to the Coast and Geodetic Survey District office. A copy of the message shall be forwarded to the Washington Office with a tracing of the boat sheet or chart showing the exact location of the danger.

2–37 Chart inspection reports.—In addition to the detailed comparison of surveys with published charts of the project area, each field party while en route to and from the project area should obtain data for revision of charts as time and circumstances permit. The fact that time does not permit the reviser to locate new features should not deter him from furnishing information about changes. New landmarks, waterfront construction, and other shoreline changes can frequently be applied to the chart by photogrammetric methods. Advance information about changes is useful when scheduling aerial photography.

The data submitted should consist of the following classes of information:

(a) Landmarks to be added or deleted.

(b) Waterfront improvements and changes.

(c) Bridges to be added or deleted. Give horizontal and vertical clearances if known and type of bridge.

(d) Removal of piling.—In marking wharves for deletion state whether piles have been removed. In the absence of definite information the feature will be retained as ruins.

(e) Rocks, shoals, and other obstructions.—Include discrepancies between charts and observed conditions, and local information on reported obstructions. Where it is not feasible to obtain positions and soundings on such reported dangers, the report should include recommendations for future surveys.

(f) Aids to navigation.—Positions of floating aids should be verified. Description, numbering, and light characteristics should be checked.

(g) Channel depths.—Report indications of shoaling in dredged channels.

(h) Cable areas.—Report new cable areas not shown on the chart. Include overhead cables with clearances.

Chart inspection notes should be accompanied by sections of charts showing corrections in red ink. The method of submitting such data is discussed in detail in The Coast Pilot Manual, Part 6.

2–38 Inspection of chart agencies.—A hydrographic party may be required to inspect chart agencies during the season. Special instructions are issued for such inspections. Forms are supplied for reporting the results of the inspection.

2–39 Landmarks for charts.—A report on landmarks for charts, in duplicate, on Form 567, is required for all hydrographic surveys. The report shall be submitted at the end of the season for the project as a whole and not for each hydrographic or topographic survey. The original copy is filed in the Chart Division as a chart letter. The duplicate copy should be marked "Coast Pilot Branch." Any sketches or chart sections submitted with the report should be cut or folded to letter size.

Reports on landmarks shall, if possible, be complete in themselves in order that further reference to triangulation data and topographic surveys may be avoided. The report shall state whether or not an inspection was made to determine the value of the landmarks when viewed from the water area.

A separate report on Form 567 shall be submitted for charted landmarks which should be deleted, either because they no longer exist or because they have no value as landmarks.

Instructions for preparing reports on landmarks, and a detailed treatment of standard nomenclature will be found in Chapter 7, Sections 18 to 22, inclusive. Note that the geographic positions of all fixed aids to navigation which were *located* during the field season must be reported on Form 567. It is important that the names of the aids entered on the form be identical with those in the Light Lists.

2–40 Photographs.—Photographs of field activities, personnel, and equipment, particularly when they illustrate actual field operations, are of considerable value. Chiefs of Party are directed to have such photographs taken whenever practicable and forwarded to the Washington Office. Photographs are particularly needed illustrating new equipment, new types of apparatus, and new techniques of field operations.

Negatives are preferable to prints since they afford better reproduction. Personal negatives may be forwarded to be copied and returned to the owner. Photographs should be comparatively large or be taken with a camera that will permit subsequent enlargement. An effort should be made to obtain sharp, distinct outlines and decided contrasts.

Photographs intended for illustrations in Coast Pilots should be taken from a position where the view would likely be most useful to the mariner. In a region where the coast may be closely approached with safety, photographs of distinctive features which may be identified during low visibility are especially useful. The title of such a photograph must always include a statement of the distance to the feature and the direction towards which the camera was pointed.

The negatives or duplicate prints of illustrations for a season's or special report should be submitted separately so that the report will not be mutilated by removing the photographs for registration and filing.

A photograph may be useless unless it is accompanied by descriptive and historical data. Each photograph, or group of photographs of the same subject, should be accompanied by Form 792, Letters Transmitting Photographs, with all necessary information entered on the form.

2–41 Report on geographic names.—When practicable, the field party should submit a special report on geographic names to cover the project area. Names already charted should be verified and not merely copied from charts or maps of the area. Inhabitants should be consulted to determine geographic names in local use. When a feature is known locally by a name which differs from the charted name, the report should include both names with the history of each and a recommendation as to which name should be charted.

The hydrographic survey should be the authority for all geographic names seaward from the high-water line, including the names of all water features such as channels, sloughs, rivers, inlets; and those of the reefs, rocks, banks, and shoals therein; and all small islands and geographic features thereon. Only a few geographic names on the mainland need be included on the smooth sheet and these principally for reference purposes.

Topographic surveys, planetable and air photographic, should be the authority for all geographic names inshore from the high-water line, including the names of all land features; and in addition the names of lakes, small streams, rivers, and sloughs which are not sounded during the hydrographic surveys.

It is particularly important that geographic names on the charts be correct as to name, but also as to spelling and application. Names should not be inked on hydrographic or topographic survey sheets by the field party. They should be lettered in pencil and should refer unmistakably to the features named. Only after verification in the Washington Office will they be inked.

For further information on geographic name investigations see Chapter 7, Sections 14 to 17, inclusive.

2–42 List of geographic names in descriptive report.—In addition to any other report or reports on geographic names, each descriptive report shall contain an alphabetical list of all of the geographic names lettered in pencil on the sheet when forwarded to the Washington Office (see 7–7). If a special report covering all of these names has been or will be submitted, the information should not be duplicated in the descriptive report, but the latter should contain a reference to the special report if new facts have been discovered relative to any

of the names previously reported on. When the alphabetical list contains geographic names which were not reported in the special report, the descriptive report should contain all of the information available relative to them.

Besides the above, the descriptive report should contain the hydrographer's recommendations for names for important previously unnamed features.

2–43 Monthly progress reports.—Each Commanding Officer and Chief of Party shall submit monthly, in duplicate, a report of activities for the preceding month. These reports shall be mailed in sufficient time to arrive at Bureau headquarters not later than the 5th of the month following the reporting period. These reports shall include all activities up to the end of the month, if possible. In cases where a report may have to be prepared before the end of the month in order to have it reach Bureau headquarters in time, activities projected or anticipated up to the end of the month shall be included in the report. This report shall also include a paragraph outlining safety activities for the month, such as programs or procedures discussed or initiated.

Each Commanding Officer and Chief of a Field Party shall mail to the Washington Office not later than the 10th day of each month a completed Form 20a, Monthly Report and Journal of Field Party. This journal should be kept current with day-to-day operations. Entries shall be made in accordance with instructions on Page One of the form. The statistical data are particularly important. A typed copy of the report is not required, but lettered or written entries must be clear and legible.

Each Commanding Officer, Chief of Field Party, and Officer in Charge of a processing office shall report, at the end of each month, on the progress of office work on smooth hydrographic sheets. Separate reports are required for each project of each vessel or field party. The report shall be submitted to Washington in duplicate on Form 118. Processing offices shall submit reports only for the surveys being processed during the reporting period, except that at the end of each quarter (31 March, 30 June, etc.) the report shall include all surveys on hand at the end of the quarter.

2–44 Monthly progress sketch. — A monthly progress sketch shall be submitted as soon as practicable after the end of each month. It should be made on tracing cloth with black ink only. The sketch and title should be neat and legible but expert penmanship is not required; mechanical lettering sets should be used.

The scale of the progress sketch is usually stated in the project instructions; otherwise it shall be that of the published chart covering the entire area of the season's work. The size of the progress sketch, in inches, should be no larger than is required to include the season's work.

Each progress sketch shall contain a title giving the following information: class of work, locality, scale, project number, dates of survey, name of vessel or party, and name of Chief of Party. The scale may be given as a ratio, or by referring to the chart from which the projection has been traced.

The sketch must contain a projection and just enough shoreline and geographic names for easy identification. Progress for all types of work should be added each month. Standard symbols shall be used as shown in Figure 3. The information should be generalized, the principal object being to report areas surveyed and in such a way that information can be transferred to the office progress charts.

As survey sheets are started and field numbers assigned (see 1–13), their limits should be shown and identified on the progress sketch, if this is practicable without confusion; otherwise the sheet layout diagram on a separate tracing should be forwarded with the progress sketch to identify the survey sheets.

The symbols shown in the upper part of Figure 3 shall be used to report progress on combined operations projects. It is not necessary to use different symbols to show hydrography accomplished in consecutive months. Additional symbols may be used as

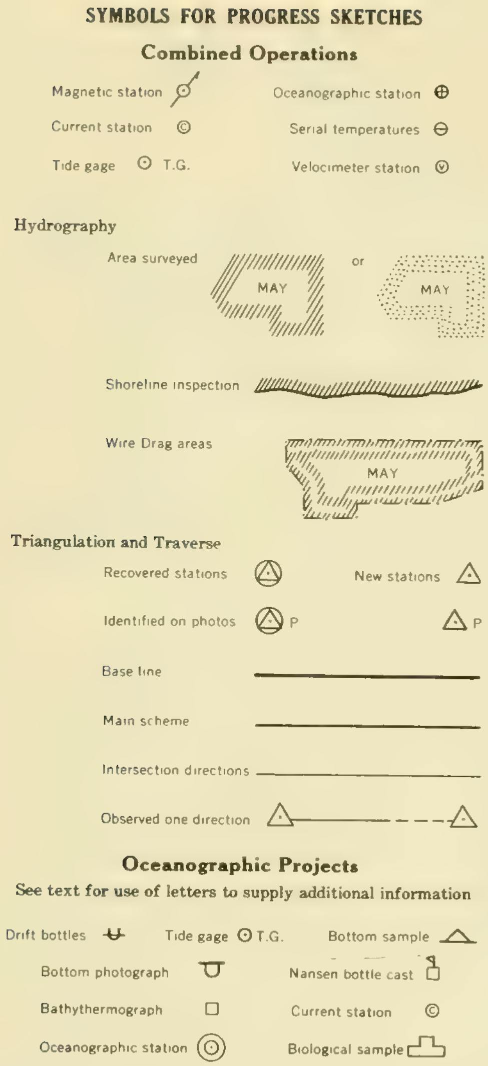


FIGURE 3.—Symbols to be used when drawing progress sketches.

necessary to report other accomplishments, but such symbols must be explained in a legend. Oceanographic observations made as part of the combined operations project shall be shown on the same sketch.

Vessels assigned to oceanographic projects shall use the symbols shown in the lower part of Figure 3 to report progress. The symbol for Nansen bottle casts shall be supplemented by letters and numbers to identify the water samples retained. A sample obtained for determination of salinity shall be identified by the letter S; for oxygen by the letter O; for phosphate by the letter P; and for nitrates by the letter N. The numbers on the sample bottles shall be shown also—as S 105–121 to show that salinity samples numbers 105 to 121 inclusive were obtained at that station.

Each bottom sample *retained for analysis* shall be numbered consecutively and the method used to obtain the sample shall be indicated on the sketch as follows: C= core; S= snapper cup; SF= scoopfish; and D= dredge. A dash line should be used to show the route of dredging.

The number of the station shall be shown beside each current station symbol and the method used to measure the currents shall be indicated by letters as follows: R= radio current meter; P= pole; PM= Price meter; and D= drogue.

Biological samples shall be numbered consecutively and the type of sample shown by letters as follows: P= plankton net; T= mid-water trawl; and D= dredge.

The identifying numbers assigned to drift bottles shall be shown beside the symbol for each drop.

Most symbols on the Oceanographic progress sketch can be drawn with a Leroy lettering guide No. 3240A obtainable from the Washington Office.

A new monthly progress sketch shall be started at the beginning of each season, and continued throughout the season, irrespective of fiscal years. On continuing projects a new sketch shall be started in January of each year. Progress sketches will be returned to the Chief of Party, without request, after the information on them has been transferred to the office progress charts.

2–45 **Season's report.**—A season's report shall be submitted by every Chief of Party prior to the beginning of the next field season or before a change of command. When field work on one project is continuous through December 31, the report shall be made as of that date if there is no immediate prospect of completing the project. The report shall be in detail, covering each project completed or in progress. A mere chronological summary of events and table of statistics are of little value in such a

report. Descriptions of, and recommendations on, new methods of field work, descriptions of new instruments and equipment, and similar subject matter should be submitted as separate special reports, but the information may be summarized in the season's report.

The following information and data should be included in the season's report:

(a) The project number and the name of the officer submitting the report at the top of the outside cover.

(b) Dates of original and supplemental instructions and of beginning and ending field work.

(c) A brief chronology of the activities of the party. A detailed report of ship movements during the field season is not desired.

(d) The general organization of the party, including a list of all officers and the general capacity in which each was employed, giving dates of reporting or detachment.

(e) A table of statistics on Form 21, Statistics and Summary of Field Work.

(f) A brief summary of methods employed in executing the work, a discussion of unusual methods used, and recommendations concerning continuation of the project, when applicable.

(g) An inventory of all computations, field records, hydrographic and topographic surveys, either completed or uncompleted, including any already forwarded to the Washington Office or to a processing office, and any remaining on hand from previous seasons.

(h) The season's progress sketch in accordance with 2–46.

(i) A separate progress sketch showing only the triangulation.

2–46 Season's progress sketch.—A progress sketch on tracing cloth, summing all the information shown on the monthly progress sketch, shall accompany the season's report. The monthly progress sketch may be used for this purpose, if desired. The title should state "Progress Sketch to Accompany Season's Report" and should include the date of closing field work in addition to the information in the title of the monthly progress sketch.

Any triangulation executed by the field party shall be shown on a separate sketch also attached to the season's report. The triangulation sketch shall be prepared in accordance with instructions on pages 191 and 192 of Special Publication No. 247.

2–47 Annual statistical report.—An annual statistical report shall be submitted by each Chief of Party as of June 30 of each year on Form 40. This report must not be delayed, and shall be forwarded not later than July 10. Statistics only are required, the information being needed for inclusion in the Director's Annual Report. A separate report must be submitted for each project. The person who is Chief of Party on June 30 shall submit this report for the entire fiscal year, regardless of the length of time he has been chief of that party.

An annual progress sketch shall accompany the report. The sketch shall be made on tracing cloth with maximum dimensions of 8 by 10½ inches. The scale of the sketch must necessarily be small and some information must be generalized to show area covered. A separate sketch is required for each project.

2–48 Objects for use in locating aids to navigation.—Personnel of United States Coast Guard tenders use the three-point fix method, wherever possible, to locate floating aids to navigation and to replace them on their stations (see 5–80). For their use in this work a special chart shall be prepared by each hydrographic party on which shall be shown the objects, natural or artificial best suited for this purpose.

During the survey each floating aid to navigation which can be located by a sextant fix shall be visited for the purpose of selecting by inspection the most suitable objects. These need not be restricted to landmarks recommended for charting; if there is an insufficiency of these in the most appropriate locations, they should be supplemented by less prominent objects, visible from the respective aids, and located specifically for this purpose. Permanent objects not likely to be

destroyed or moved shall be selected. The use of day beacons, range marks, targets, etc., should be avoided.

The objects selected shall be plotted on a copy of the latest print of the largest-scale chart of the area. A short legend and the date of the field survey or number of the topographic sheet of the area shall be shown on the chart. The three or four objects selected for each fix shall be encircled in red on the chart, whether already charted as landmarks or plotted by the survey party. Adjacent to the position of each object selected, a description from which the object may be identified shall be noted in red. The fix, and check angle, selected for each aid shall be indicated on the chart by red arrows at the aid, pointing toward the object to be used.

The prepared chart, after the information thereon has been carefully verified, shall be forwarded directly to the Commander of the Coast Guard District in which the area is located, with a transmitting letter stating its purpose. Explanatory information for proper interpretation of the data on the chart shall be included if necessary.

The following data should be sent to the Washington Office:

(a) A copy of the transmitting letter.

(b) A list of the objects plotted on the chart with their latitude and longitude and method of location. The list shall be prepared on Form 567, Landmarks for Charts, and should include only those objects not already charted. The title on the form should be cut off, or marked out, and a new heading "Objects for use of U.S. Coast Guard" written in.

The transmittal of these data shall be handled as a separate subject, and no other field information or notes shall be included in the envelope.

2–49 Tide stations.—Tidal data are required for determination of the various datum planes (see 1–45), for prediction of tides, and for use in a hydrographic survey. Tide stations shall be established in the immediate vicinity of the hydrographic operations in order that the soundings may be accurately reduced to the sounding datum (see 5–102). The number of stations required depends on the character of the area; where the flow of tide is restricted, numerous gages may be required to determine accurate tidal constants (see 1–46). The selection of sites for the tide gages to be used in hydrographic survey is usually made in the Washington Office and is specified in the project instructions. This prior selection does not relieve the Chief of Party from a responsibility to make a study of the tidal regime of the project area. A discussion of locations of secondary tide stations is contained in paragraphs 168 to 177 in Special Publication No. 196, Manual of Tide Observations. When unusual conditions of land configuration or weather greatly affect the tide, extreme care is required to avoid large errors in tide reducers.

2–50 General plan of tide stations.—In most cases, an existing primary tide station in the general vicinity of the project will be used as the control station. In other cases, a standard automatic gage shall be installed at a central point to serve as a control station and shall be maintained in operation during the entire period covered by the survey. As the work progresses, secondary tide stations are established at other places in the immediate locality being sounded. When practicable, observations at each secondary station shall be continued over a period of not less than 29 days. Adjacent secondary tide stations in a project area should be operated simultaneously for a period of approximately 2 weeks, if practicable, especially when time or range factors change appreciably. A portable automatic tide gage is usually used for this purpose. Detailed descriptions of the tide gages with full instructions for their installation and operation are contained in Special Publication No. 196.

2–51 Bench marks and leveling.—At each tide station there must be a tide staff connected by levels with at least three substantial bench marks, so located that they will not all be likely to be destroyed by a common

cause. Search shall be made for all old bench marks in the general vicinity, their present condition shall be noted, and the old descriptions revised if necessary. New bench marks should be clearly described so that they may be readily recovered and identified. When a bench mark of another organization is recovered and connected by leveling with the Coast and Geodetic Survey bench marks, the number or name assigned it by the organization is to be retained with such additional abbreviations as may be necessary to identify the organization.

When a tide gage is discontinued, check levels between the tide staff and not less than three bench marks shall be run to ascertain whether there has been any change in the elevation of the staff during the observations. These levels shall be recorded in Form 258—Leveling Record—Tide Station, and immediately forwarded to the Washington Office. Instructions for establishment of bench marks and for leveling are contained in Special Publication No. 196.

2–52 Tide station reports and records.—Report—Tide station, Form 681, shall be submitted, in duplicate, immediately for each tide station established. The exact location of each tide station shall be shown on each hydrographic sheet (see 6–71). The time meridian used shall be indicated in the tide records. The tide records for portable gages shall be forwarded for each two weeks of satisfactory operation, if practicable. When a standard gage is used the marigram should be changed at the end of each calendar month. When a station is discontinued, the fact shall be noted on the original record.

The hourly heights required for reduction of soundings shall be tabulated before the marigrams are forwarded to the Washington Office. The datum or plane of reference will be derived in the office and furnished the field party on request. If a primary tide station is used for reduction of soundings, the hourly heights for the station will be furnished by the Washington Office on request.

2–53 Tide predictions.—A knowledge of the approximate tide is necessary in connection with almost all operations of a hydrographic survey party. It is sufficient, at times, to know the predicted time and heights of high and low water, but for some operations more exact values are necessary. When the hydrographic survey is of an area with a comparatively large range of tide or where the bottom is even, predicted tides must be used for the preliminary reduction of soundings for boat sheet plotting. These predictions may usually be obtained with sufficient accuracy from the Tide Tables, but in some instances a predicted tide curve may be needed and will be furnished by the Washington Office, on request.

When the Tide Tables are used, the procedure is as follows:

(a) From Table 2 find the tide differences applicable to the area being surveyed. Apply these differences to the tide predictions for the reference station and obtain corresponding times and heights of the high and low waters covering the period of the work.

(b) On cross section paper, as illustrated in Fig. 4, plot the low- and high-water point A and E in accordance with time and height coordinates. Three cross section forms are available for use depending upon the reducer unit to be used: 114 for 0.2 foot, 115 for 0.5 foot, and 116 for fathoms.

(c) Divide the connecting line AE into four equal parts at points B, C, and D.

(d) Take point B′ vertically below B and D′ vertically above D equal to one-tenth of the range of tide.

(e) Draw an approximate sine curve through points A, B′, C, D′, and E. This curve will closely approximate the actual tide curve and the required data may be readily scaled from it.

On the tide curve thus constructed, the points at which changes in reducers occur can be marked. A tabulation of reducers and times of change can then be taken from the curve and furnished each unit before starting the day's work.

2–54 Predicted tide curve.—When a pre-

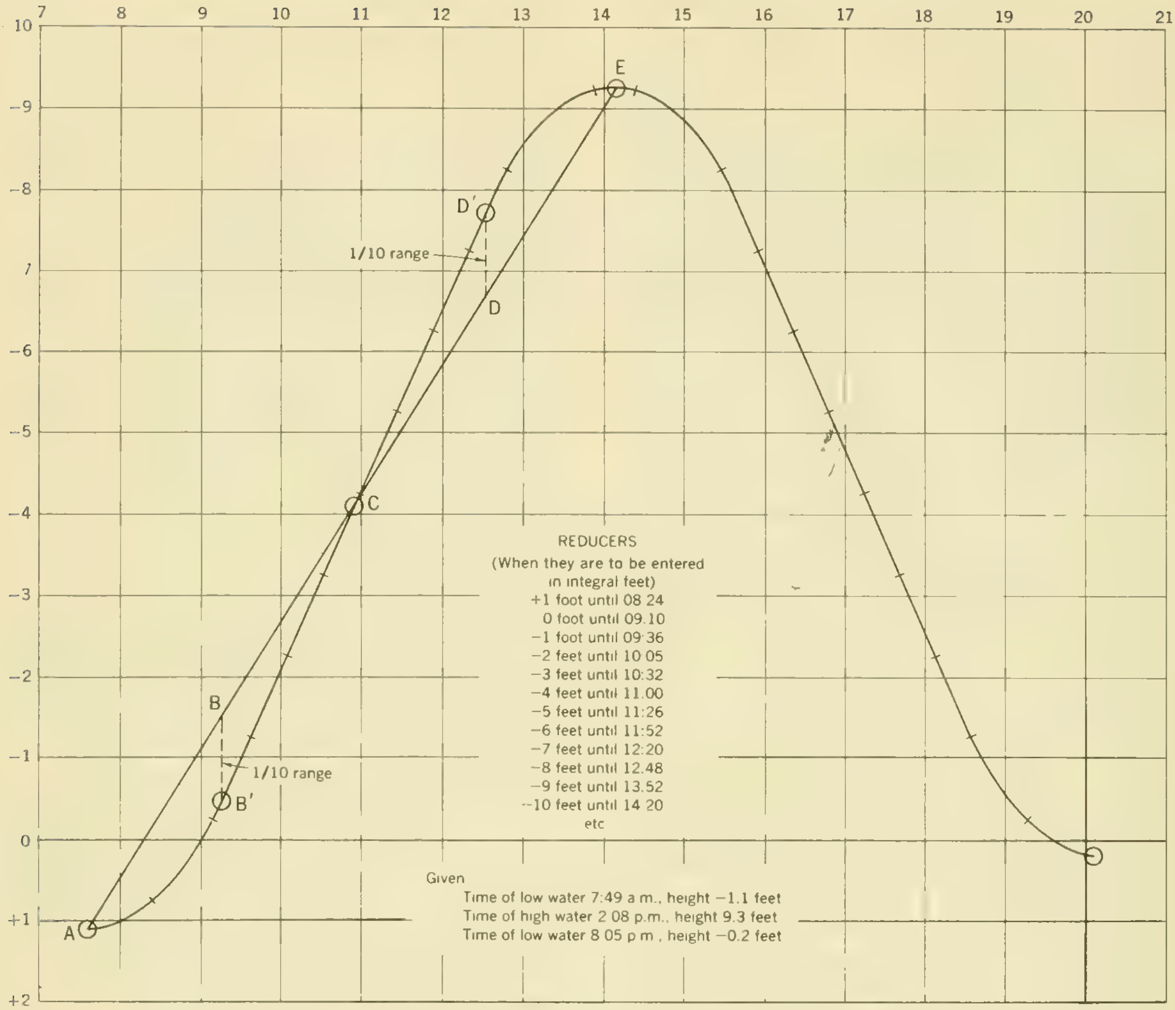


Figure 4.—Construction of predicted tide curve.

dicted tide curve for a reference station is furnished by the Washington Office, a time correction and range factor will usually be necessary to make the curve applicable to the project area. These corrections will generally be indicated on the curve by the Office.

The predicted tide curve furnished by the Washington Office is on a long roll of paper 6 inches in width. If it is to be used extensively it will be convenient to construct a small wooden box containing two spools, each of which can be turned by a crank. By these cranks the roll of paper can be wound from one spool to the other, passing over the flat top surface of the box where it is exposed to view between the two spools.

a. **Time correction.**—If the tides in the area sounded occur earlier or later than at the reference station, the original numbering of the hour marks must be decreased or increased, respectively, by a corresponding amount. The hour marks on the tide curve are usually not numbered, but the beginning of each day can be identified by a double downward jog in the datum line. With a time allowance of +1 hour this double jog will be taken as 1:00 to adapt the curve to the working ground, but if the time allowance is −1 hour the double jog will be taken as 23:00 or the preceding day.

b. **Range factor.**—The allowance for the difference in range can be most conveniently

made by the use of an improvised scale, on a strip of celluloid or paper, representing the product of the original marigram scale by the reciprocal of the *ratio of the ranges*, as taken from the Tide Tables. Thus, if the marigram scale is 1/30 and the ratio of the ranges 0.8, then the improvised scale is placed on the marigram with its zero at a distance below the datum line equal to the depression of the plane of reference below mean sea level or half-tide level. For the Atlantic Coast, this depression is approximately the half range of tide at the working ground. For the Pacific Coast, it will be the half range of tide plus the diurnal low-water inequality. Where there have been previous tide observations in the locality, the relation of the plane of reference to half-tide level can usually be taken directly from the bench-mark data.

Where previous tide observations are not available, an approximate setting of the improvised scale on the datum line can be obtained by multiplying the ratio of the ranges for the working ground by the depression of the datum plane below mean sea level at the reference station. The depression can be found in the List of Reference Stations preceding the daily predictions in the Tide Tables. Thus, if the ratio of the ranges at Oakland (the working ground) is 1.2 and the plane of reference at San Francisco (the reference station) is 3.0 feet below mean sea level (from List of Reference Stations), then the setting of the scale on the datum line of the marigram would be 3.0 feet x 1.2 = 3.6 feet.

3. EQUIPMENT AND INSTRUMENTS

3–1 **Survey ships.**—A modern major survey ship (Class I) is designed to carry on combined operations projects in offshore and remote areas. Each one is a complete and independent unit fully equipped with modern navigational and survey instruments. There are accommodations for a complement of 12 to 20 officers and 70 to 90 men. The storage space is sufficient to carry supplies for about 6 months' operation. Fuel and water capacity enables the ship to remain in the project area for 3 to 4 weeks, if necessary. The ship will usually carry four launches, one of which may be a landing craft, and several small boats such as whaleboats, skiffs, or dories.

A survey ship should be designed to accomplish her mission efficiently and in safety. Suitable quarters for the ship's complement, adequate storage space for supplies, sturdy ground tackle, steering engine, and launch hoisting gear are essential in a survey ship. A well-lighted and fully-equipped drafting room (Fig. 5) and a large well-equipped navigating bridge must be provided. There must be space for installations of echo sounders and electronic positioning equipment in or just aft of the bridge area.

Deck space for installing sounding machines and oceanographic winches should be available on the bridge deck or immediately below it. Nearly every operation of a hydro-

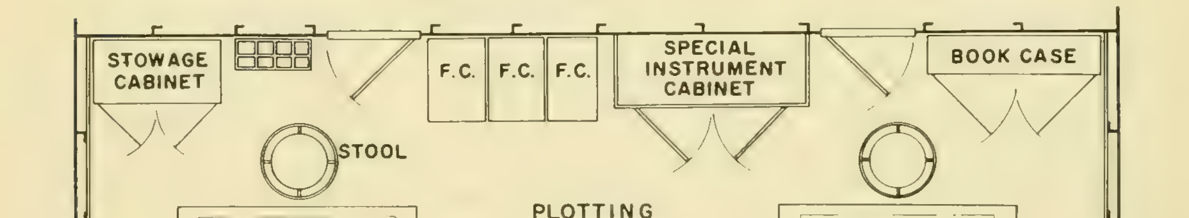


FIGURE 5.—Drafting room of a survey ship.

graphic survey ship requires the use of electric power and the generators must have a capacity sufficient to supply power to all equipments which may be in operation simultaneously.

A well-designed ship will provide spaces for an oceanographic laboratory, a photographic laboratory, a sick bay, and work shops for engineers, electronic technicians, and carpenters.

Smaller survey ships are small models of the major ships and vary in size and mission. Class II ships have accommodations for 8 officers and 50 men, and are able to work in exposed areas, but for shorter periods of time. Small auxiliary survey vessels are designed for operations in harbors and sheltered areas close to a source of supplies. Some are designed for specific duties such as wire-drag surveys or current observations.

3–2 Survey launches. — The ship's launches, which also serve as lifeboats, will vary in size with the class of ship, and range from 26 to 36 feet in length (Fig. 6). Launches for hydrographic work generally have a covered cockpit forward in which are located a plotting table, echo sounder, and electronic positioning equipment, if used. The plotter, recorder, and echo-sounder operator are stationed here. This cockpit should be weather-proof and well lighted. The steering station is located on a raised deck amidship. Sextant angles are observed from this station when visual control is used. The launch is powered by a Diesel engine housed in a covered cockpit aft. Engine controls are usually mounted at the steering station. Storage batteries for operation of echo sounders and radiotelephone are charged by a generator driven by the main engine. If Shoran equipment is used, a separate power supply is required, and is usually a small Diesel-driven generator mounted in the engine compartment.

FIGURE 6.—Modern hydrographic survey launch.

One of the ship's launches is usually designed as a work boat for transferring personnel, equipment, and supplies between the ship and the beach. This will include lumber, camp gear, or equipment for electronic stations. A small landing craft is most suitable for this purpose. The boat may be used by signal building, triangulation, or photogrammetric parties.

The launches should be strongly built to withstand daily use and severe strains to which they are subjected by frequent lowering and hoisting under adverse conditions of sea and swell and the occasional groundings which are unavoidable on inshore hydrography. Each launch should be equipped with lifeboat gear, a portable echo sounder, and a radiotelephone (see 2–26).

3–3 Small boats.—Each ship will carry one or two powered whaleboats which are combined lifeboats and work boats. They are very useful for supplying camp parties, tending tide gages, and similar operations where launches are not required. The ship will also carry a number of skiffs or dories as may be required by the nature of the assigned project. In shoal water bays and sounds along the Atlantic and Gulf Coasts hydrographic surveys are frequently conducted with specially designed skiffs powered by outboard motors. The Chesapeake Bay skiff is typical of this class of boat.

3–4 Navigation equipment.—Every survey vessel, regardless of size, must be properly equipped with modern instruments for safe navigation. These include compasses, chronometers, sextants, charts, Coast Pilots, Light Lists, etc. The larger vessels will be equipped with Standard Loran, radar, and gyro compasses. The Commanding Officer, assisted by the navigating officer, is responsible for the care and maintenance of all instruments, equipment, and supplies necessary for safe navigation. Magnetic compasses, both standard and steering, must be properly compensated and compass errors known even though the ship is equipped with a gyro compass system (see 2–28). Instructions for adjustment and compensation of magnetic compasses will be found in H.O. Publication No. 9, Bowditch, (1958 Edition) and in H.O. Publication No. 226, Handbook of Magnetic Compass Adjustment and Compensations.

3–5 Care of survey instruments.—A ship has two general classes of survey instruments: (1) those permanently installed, and (2) portable instruments. The first group includes large equipage as electric sounding machines and oceanographic winches, deep water echo sounders, and electronic position fixing equipment. The second group includes all small survey instruments and some portable equipment such as shoal water echo sounders and current buoys and meters.

The Chief of Party, navigating officer, or other officer specifically assigned such duty, is responsible for the proper care and maintenance of all survey instruments and equipment. Various members of the ship's complement may be required to service and maintain these instruments. The electronics or radio department is charged with the care of all echo sounders, electronic position fixing equipment including radar and Loran, all radio equipment, and may be responsible for servicing the gyro compass. A service manual is provided with each equipment. Subsequent discussion will refer only to the use of these instruments and precautions to be observed.

The Engineer Department shall service and maintain the deck machinery including all hoists and winches. The Chief Quartermaster and his assistants are responsible for proper care and storage of all other survey instruments.

Instruments in daily use must be carefully cleaned, dried when necessary, and properly stored after being returned from the field. Abrasive cleaners must not be used on graduated arcs or circles or on sextant mirrors. Only approved grades of instrument oils shall be used. The navigating officer should supervise this work, make periodic inspections of instruments, test and adjust them when necessary, maintain an accurate inventory of instruments, and make any repairs that can be accomplished in the field. At the

end of the field season, worn out, damaged, and surplus instruments should be returned to the Washington Office, or stored at a District Office in accordance with Bureau Regulations.

Equipment installed where it is exposed to the weather should be kept covered when not in use. During the layup period, or if the machines are used infrequently, they should be examined periodically to see that motors are operating properly and all moving parts move freely.

3–6 Instrument requisitions.—On receipt of instructions for a survey project, the instrument inventory should be examined to determine what additional instruments, if any, will be required to accomplish the work (see 2–17). All items of equipment and instruments are obtained from the Washington Office by requisition of the Chief of Party, using Form 12, Property Requisition. The requisition should be submitted sufficiently in advance of needs to allow adequate time for packing, boxing, and shipping.

Immediately on receipt of a shipment of instruments, the Chief of Party should have the items checked with those shown on the invoice. Each instrument should be closely examined and tested to see that it is in good working order. Any discrepancy, or any damage to instruments, should be reported to the Washington Office at once.

3–7 Shipment of instruments.—Instruments that are returned to the Washington Office, transferred to another ship, or placed in storage, shall be reported on Form 573, Property Storage and Transfer Report. Each instrument to be shipped must be firmly secured in its box, but in such a manner that delicate parts will not be injured because of excessive pressure. Special precautions must be used in preparing some instruments for shipment, loose pieces should be securely lashed, the glass face of a clock must be well-padded with shredded paper, a compass should be removed from its gimbals, and the balance wheel of a chronometer must be locked with small cork wedges. Instruments generally are expensive precision mechanisms and are easily damaged in shipment if not carefully packed.

3–8 Position locating instruments.—There are two general methods of locating a sounding vessel when engaged in hydrography. Inshore surveys are usually controlled by three-point fixes using hydrographic sextants to measure two angles between three known points, one of which is common to both angles. The position is plotted by a three-arm protractor. Offshore hydrography, and some inshore surveys, are usually controlled by an electronic distance measuring system and may be Shoran, Raydist, or Electronic Position Indicator. Positions are plotted by an Odessey protractor. The various instruments used to determine and plot positions are described in the following sections.

3–9 Sextants.—The sextant is a hand-held instrument used for measuring an angle between two points and has a maximum range of about 140°. There are two general classes of sextants: (a) the navigating sextant which can be read to 10 seconds or 0.1 minute according to the design, and (b) the hydrographic sextant which is usually designed for measuring an angle to the nearest minute. Sextants are also classified as vernier or micrometer drum according to the method used to obtain the final reading. See Chapter 15, Bowditch (1958) for a complete discussion of the various types of sextants available.

With the clamp screw vernier sextant, the index arm is set at the approximate angle and the arm firmly clamped to the frame. The two objects are brought to coincidence by use of a tangent screw of limited range. Modern vernier sextants have a worm gear attached to the arm which engage a matching gear on the frame of the sextant and permit unlimited movement of the arm with the tangent screw.

The micrometer drum sextant (Fig. 7) also has an endless tangent screw but the final reading is made on a graduated drum rather than a vernier. The drum may be graduated to 10 seconds, 0.1 minute or 1 min-

ute of arc. This type of sextant is preferred by most observers; however, it is sometimes difficult to measure an angle accurately with this sextant when the angle is changing very rapidly.

A navigating sextant shall always be used for astronomic observations, for measurement of angles to locate a hydrographic station, and for observing small vertical angles.

3–10 Adjustment of sextant.—The adjustments of all sextants used in hydrographic surveying should be verified, and readjustments made if necessary, each morning before the start of the day's work. They must be verified each night at the close of the day's work. The fact that this has been done at both times and the amount of the index correction found at the end of the day, if any, must be entered in the sounding record (see 5–90 and 98).

A sextant should be adjusted as follows: the index mirror (the large mirror on the movable arm) must first be made perpendicular to the plane of the instrument. To make this adjustment, set the index arm near the middle of the arc and hold the sextant with the eye close to the index mirror and as nearly as possible in the plane of the sextant. Observe the graduated arc direct and its reflection in the index mirror, moving the arm slowly back and forth. The arc and its reflection should form an apparently continuous unbroken arc if the mirror is perpendicular to the plane of the arc. If it does not, correct the position of the mirror by adjusting the screw at the back of the frame.

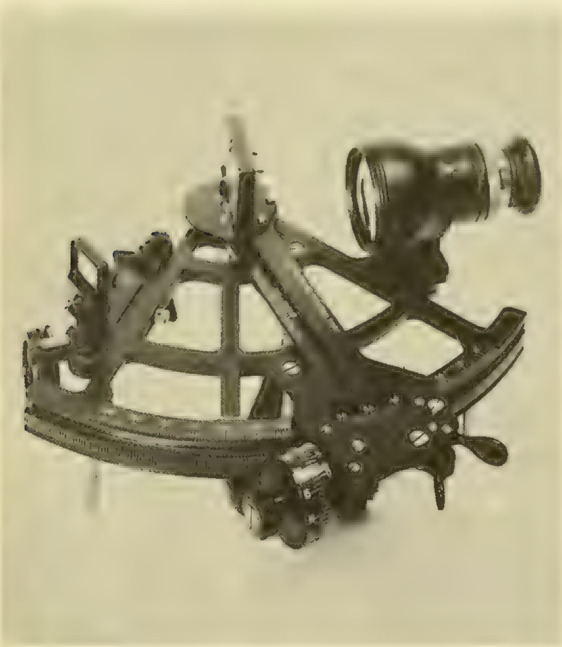


FIGURE 7.—Micrometer drum sextant with endless tangent screw.

The horizon mirror should now be adjusted perpendicular to the plane of the arc. With the index mirror in adjustment, set the index arm near zero and hold the sextant so its plane is vertical and sight at the sea horizon. Bring the horizon and its image into coincidence with the tangent screw. Rotate the sextant slowly and see if the horizon and its image are still in coincidence. If not, adjust the position of the mirror by means of the screws at the back of the frame until coincidence is obtained.

Finally, the two mirrors should be parallel to each other when the index arm is set at zero. After making the two adjustments described above, set the index arm exactly at zero and, with the sextant in a vertical position, sight at the horizon. The observed and reflected horizon should coincide. If they do not, adjust the mirror by means of the screws at the side of the mirror until coincidence is achieved. If this last adjustment is required, it may disturb the vertical adjustment. Both should be repeated until the horizon mirror is adjusted for any position of the sextant.

3–11 Index error of sextant.—The index error of a sextant is due to the fact that the reflecting surfaces of the mirrors are not parallel with each other when the index arm is set at zero. The amount of the index error, if any, can be determined by one of the following three methods:

(a) With the sextant held vertically and pointed at the sea horizon bring the direct and reflected images into coincidence and read the setting of the index arm. Repeat several times, bringing the reflected horizon

down to coincidence and up to coincidence alternately, taking a mean of the results. If the zero of the vernier is to the right of the zero of the arc, or *off the arc*, the correction is positive and should be added to measured angles. If it is to the left, or *on the arc*, the correction is negative and should be subtracted from the measured angles.

(b) Substitute a star at night for the sea horizon, point the sextant at the star and bring the direct and reflected images into coincidence and read the setting of the index arm. Repeat several times and use a mean of the results as above.

(c) Measure the apparent diameter of the sun with the sextant held vertically, bringing the upper limb of the reflected image to touch the lower limb of the direct image. Read the angle. Then bring the lower limb of the reflected image to touch the upper limb of the direct image and read the setting *off the arc*. Half of the difference of the two readings is the index correction, positive or negative as the larger of the two values is off or on the arc, respectively. For example, if the diameter measures 33′50″ on the arc and 32′40″ off the arc, the index correction would be $\frac{1}{2}$ (33′50″–32′40″)=35″ (Minus). Several such observations should be taken and the mean used. The accuracy of the result may be verified by comparing the sun's semidiameter for the date of observation as taken from the Nautical Almanac with one-quarter of the sum of the two readings irrespective of sign.

3–12 Sextant mirrors.—Stellite mirrors are used almost exclusively in the Coast and Geodetic Survey. Stellite is a trade name for an alloy of chromium, cobalt, and tungsten. These mirrors have a front reflecting surface which eliminates errors due to nonparallelism of the two surfaces of glass mirrors. The surface must be polished, optically flat, free of scratches and other inperfections.

Stellite mirrors are practically indestructible if given reasonable care. The material is expensive and difficult to obtain. They should not be expended when no longer considered usable in the field. Unserviceable mirrors should be returned to the Washington Office for repolishing and checking for optical flatness.

3–13 Use of sextant.—To measure an angle between two objects with a sextant, the observer looks at the one on the left over the top of the horizon mirror and moves the index arm until the reflection of the right-hand object is seen, by double reflection, in the horizon mirror directly under the left-hand object. With both objects in view they are brought into coincidence with the tangent screw.

When the objects (signals) are definite and readily visible, many observers use the sextant without a telescope, especially if the angle is changing rapidly or the sounding vessel is unsteady. When the objects are distant, indistinct, or indefinite, when the angles are changing slowly, and particularly where a small error in the angle will affect the position considerably, a telescope should always be used (see 5–40).

Little experience is required to measure sextant angles between prominent objects when the angle is changing slowly and the observer's platform is steady. In hydrographic surveying, the circumstances are often reversed—angles change rapidly, objects are indistinct, and the survey vessel is far from steady. Under such conditions, a great deal of practice is required to enable one to observe sextant angles quickly and accurately.

As a general rule, after taking an angle and reading it, an observer should not move the index arm until the position has been plotted, so that he can verify the reading if necessary. It is always good practice to verify the reading of a sextant angle before the arm is moved.

The two angles of a three-point fix must be measured simultaneously on signal, at the word "mark." If one of the objects cannot actually be seen or if they are not in coincidence at the "mark," the angle must be reported to the officer-in-charge as a "miss."

3–14 Angles to faint objects.—When signals are faint, it is sometimes difficult to reflect the right-hand object even though

they can be seen fairly well when looking directly at them (see 5–40). In such cases the sextant should be set to the expected angle at the next position so that the reflected image of the right-hand object will be in the field of view of the telescope. There are several methods of finding approximate angles:

(a) The angle may be scaled from the boat sheet with a protractor at the approximate location of the next position to be fixed.

(b) If the angle is not changing too rapidly, the rate of change between the two preceding angles may be applied to determine the approximate angle at the next fix.

(c) The relation between the faint signal and a conspicuous object near the signal may be noted and that object reflected first. A slight movement of the sextant will bring the signal within the field of view.

(d) If the observer first determines the angle subtended between the ends of thumb and little finger with the arm outstretched, he can roughly approximate an angle by sighting over his hand and stepping off the angle along the horizon.

If the center object is difficult to reflect, the observers may measure the right angle and the sum angle between the right and left objects, subtracting the former from the latter to obtain the left angle. If the right-hand object is difficult to reflect and left one very distinct, the sextant may be held upside down to look directly at the right-hand object and reflect the left-hand one. This is an awkward procedure but may be necessary occasionally.

3–15 Inclined angles.—Sextant angles for control of hydrography should be measured between objects in approximately the same horizontal plane as the observer. If it is necessary to measure an angle between two objects having considerable difference in elevation, the angle must be corrected before it is used for plotting. When one of the objects is at or near sea level and the other at a sufficient elevation to cause an appreciable error, the inclined angle may be corrected by use of the graph in Figure 8. This graph is based on the formula:

$$\text{Cos } C = \frac{\text{Cos } O}{\text{Cos h}}$$

in which C is the horizontal or computed angle, O is the observed inclined angle, and h is the angular elevation of the elevated object from the point of observation.

To find the correction to an observed angle, enter the graph at the left-hand margin with the altitude angle as an ordinate and from this point extend a line horizontally until it intersects the curve representing the observed inclined angle, interpolating between the curves if necessary. The abscissa of the point of intersection read on the horizontal scale at the bottom of the graph will give the correction to be applied. The correction is subtractive for angles less than 90 degrees, and additive for angles greater than 90 degrees.

3–16 Protractors.—Three-point sextant fixes are plotted graphically with three-arm protractors. There are two types of protractors in general use: (1) the metal three-arm protractor and (2) three-arm plastic protractors constructed of transparent material in two sizes.

3–17 Metal three-arm protractor.—The metal three-arm protractor (Fig. 9) consists essentially of a graduated circle about 6 inches in diameter with one fixed and two movable arms pivoted at its center so that the extension of each fiducial edge always passes through the precise center of the graduated circle. The arms are about 18 inches long, and each arm is fitted with a removable extension about 15 inches long. The circle is graduated to half-degrees and has a vernier and tangent screw on each movable arm which permits a setting to the nearest minute. The graduations of the circle should be accurate to within one-half minute, and the arms should be truly radial also within one-half minute.

The center arm of the protractor is fixed at the zero of the scale. The graduations of the circle are marked with two sets of numbers so that angles may be read to the right or left of the zero of the scale. The con-

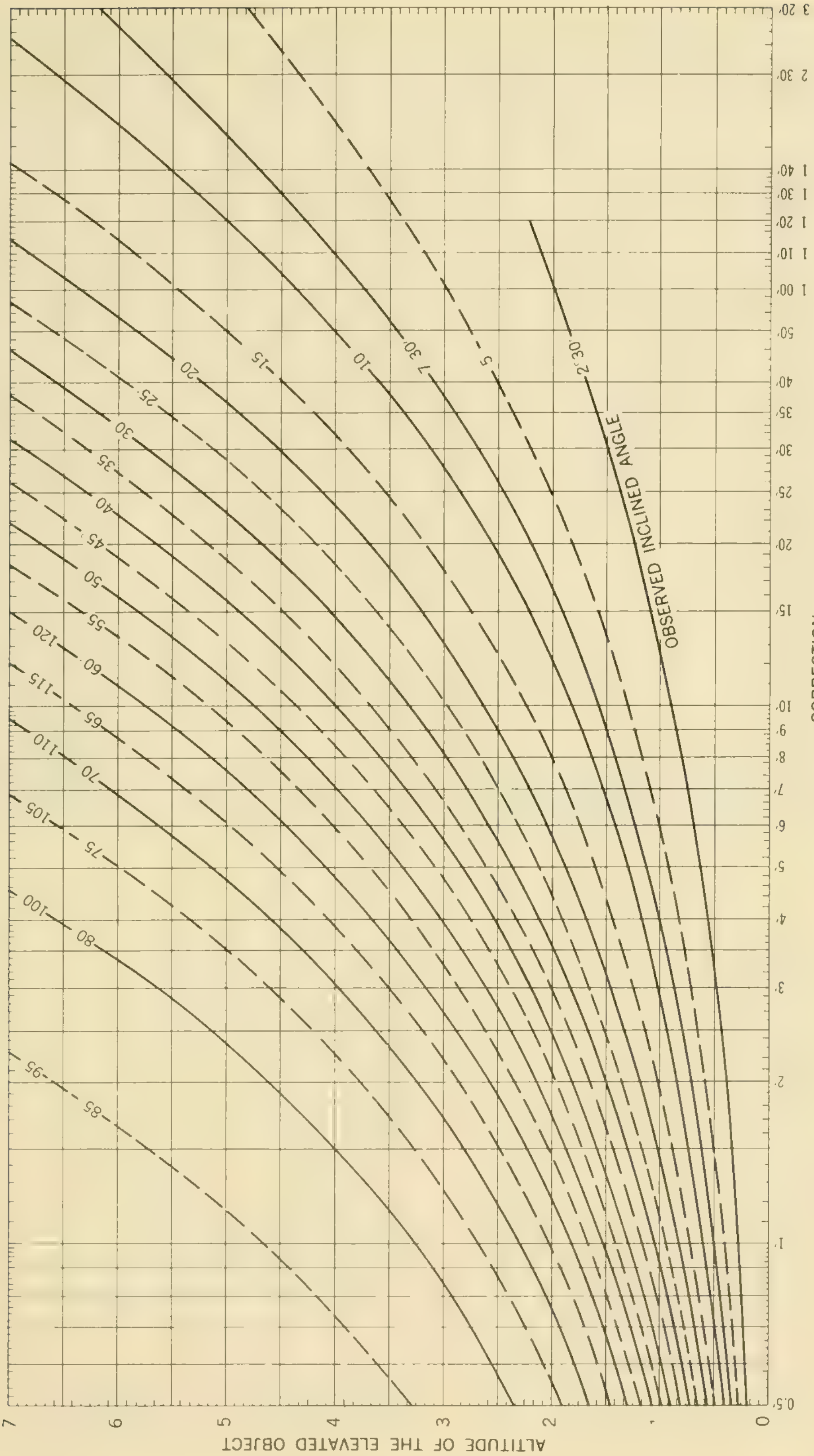


FIGURE 8.—Corrections to inclined sextant angles when one object is elevated appreciably above sea level.

FIGURE 9.—Three-arm metal protractor.

struction of the protractor permits setting a small angle approaching 0° on one arm only, the minimum angle which can be set on the other arm is about 12°. In order to plot all three-point fixes, two metal protractors are required, one constructed to accommodate a small right angle and the other to accommodate a small left angle. A magnifying glass of low power is attached to the instrument so that it can be rotated around the center in order to facilitate reading the graduated circle. At the center of the protractor is an open metal socket into which can be fitted any one of three centerpieces.

3–18 Test and adjustment of three-arm metal protractor.—Metal protractors should be tested, and adjusted if necessary, before the beginning of a field season, before plotting a smooth sheet, and at least once a month during their use (see 6–48). An aluminum plate with test lines accurately drawn will be furnished by the Washington Office on request.

In testing a protractor the centerpiece with the transparent bottom and crosslines should be used. Place the center of the protractor exactly over the intersection of the test lines and rotate the centerpiece. The intersection of the crosslines should coincide with the intersection of the test lines at all times. The pricker centerpiece may be tested in a similar manner by pricking several points in paper as the pricker is rotated. The prick points should coincide in one hole.

Each arm of the protractor should be tested for straightness against a straight

edge. The extension arms should be attached while this test is being made. An arm may also be tested by drawing a fine line along the fiducial edge and then reversing the arm to the opposite side of the line (see 3–140). If the fiducial edge still coincides with the pencil line, the arm is straight.

After the arms and centerpieces have been tested, the protractor should be placed on the test plate and centered precisely at the intersection of the two lines at right angles. The fixed arm should be moved to coincide with the central line and the right and left arms moved to coincide precisely with the lines at 90° to the central line. The movable arms should be clamped in this position. If the angles read exactly 90° the verniers are in adjustment; if not, the verniers should be moved to read exactly 90° and the test repeated.

After making this standard test, the arms should be moved to a closed position and the vernier settings at this position recorded on the inside of the storage box. A frequent check on the vernier adjustment is then possible simply by comparing the closed arm vernier setting with the recorded values. This is a safeguard against loss of vernier adjustment, but does not alter the requirement for periodic standard tests.

3–19 Manipulation of metal protractor.—To plot a three-point fix, the left and right angles are set on the graduated circle, the final setting being made by the tangent screw. The instrument should be grasped by the metal circle and the *fixed* arm, and centered at the approximate location of the fix. With the fingers of one hand used as a guide to keep the fixed arm bisecting the center station, the protractor is moved toward or away from the other stations until each arm bisects its respective station. A prick mark, or a pencil mark, is then made at the center of the protractor representing the location of the observers at the time the angles were taken. A movable arm should not be used to guide a protractor into position.

3–20 Plastic protractors.—A transparent three-arm protractor (Fig. 10) is constructed of clear non-flammable plastic, with a solid disk about 12 inches in diameter containing a circle graduated in degrees, and one fixed and two movable arms each containing an etched line radial with the center of the protractor. Each movable arm contains a vernier graduated in two-minute intervals. There are two sizes of plastic protractors—one has arms about 13½ inches long and the second is constructed of heavier gage material with arms 24 inches long.

Although slightly less accurate than the metal protractor, the plastic protractor has several advantages. Its transparency makes it possible to plot positions close to control stations. It is lighter in weight, more easily read, and can be more quickly set than the metal protractor.

3–21 Testing three-arm plastic protractors.—A plastic protractor cannot be adjusted. It should be tested to see that the plastic has not warped and to determine the index correction. The radial lines should be checked for straightness by superimposing the lines over a steel straightedge. Place the protractor on the test plate, match the etched lines with the lines on the test plate at 30°, 60°, and 90° and read the angles on the protractor. The differences, if any, represent the index corrections of the respective arms.

Plastic protractors used for smooth plotting (see 6–48) shall be calibrated as follows: On a section of metal mounted drawing paper draw a straight line and carefully construct a perpendicular, (Fig. 11). From Point A measure off 50 centimeters to Point B on the first line. From the same point measure 18.2 centimeters (50 cm $\times$ tan. 20°) on each perpendicular to points C and C′. With the center of the protractor at position B and the fixed arm through A, the angles to left and right through C and C′ should be exactly 20°. Differences therefrom may be used as index corrections being sure to apply them with the proper sign. Plastic protractors used for smooth plotting should be compared with the standard daily.

3–22 Odessy protractors.—When hydrog-

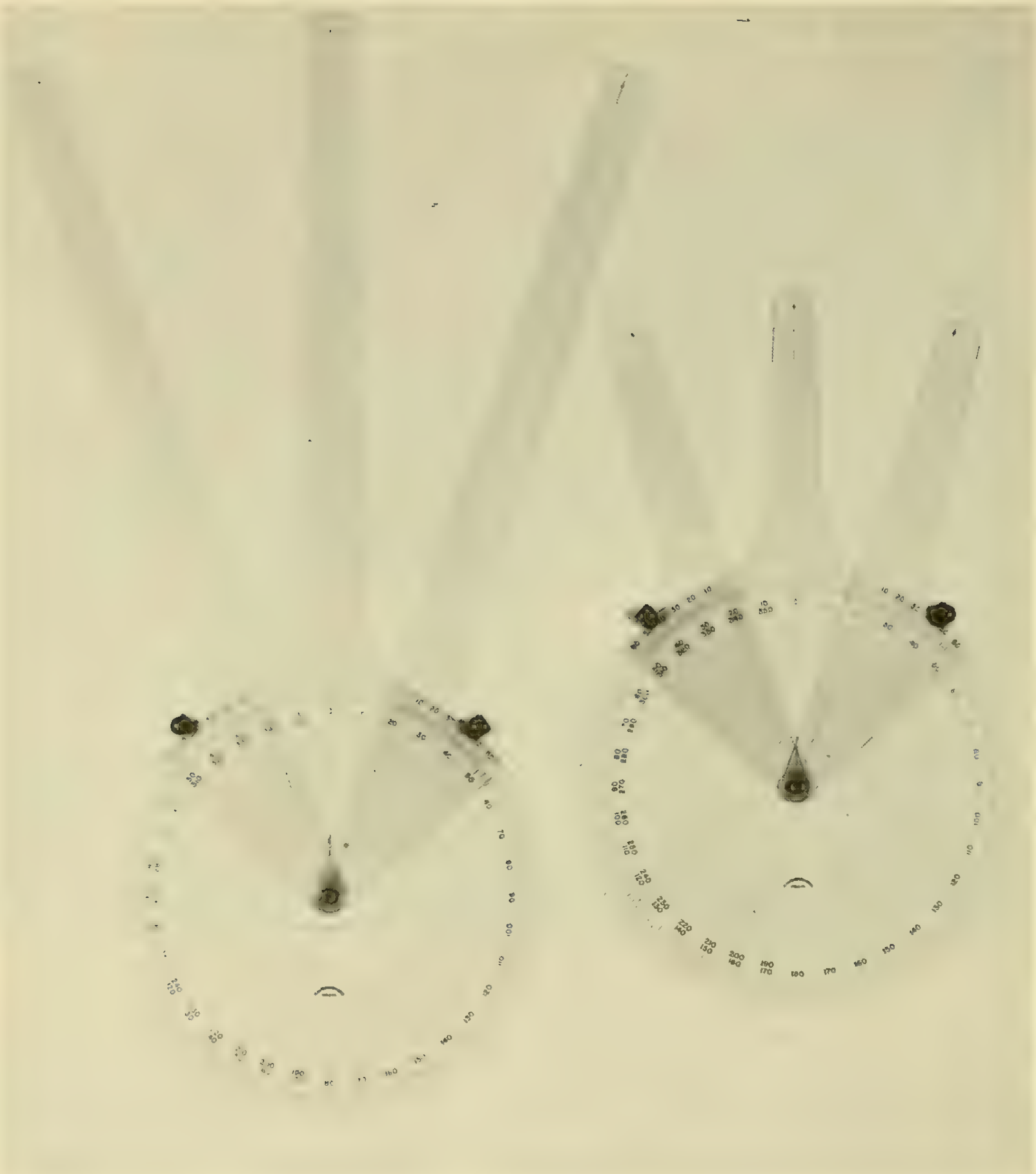


FIGURE 10.—Three-arm plastic protractors.

raphy is controlled by electronic devices which measure distances to fixed stations, positions are plotted by an Odessey Protractor (Fig. 12) with reference to distance circles drawn on the sheet (see 5–50). This device is simply a series of closely-spaced concentric circles drawn on clear plastic material to represent distances from the center in terms of miles, microseconds, or lanes, to fit the system in use. A protractor must be constructed to suit the type of electronic equipment to be used and the scale at which the survey is to be plotted. The diameter of the outer circle on the protractor is double the interval between distance circles on the sheet.

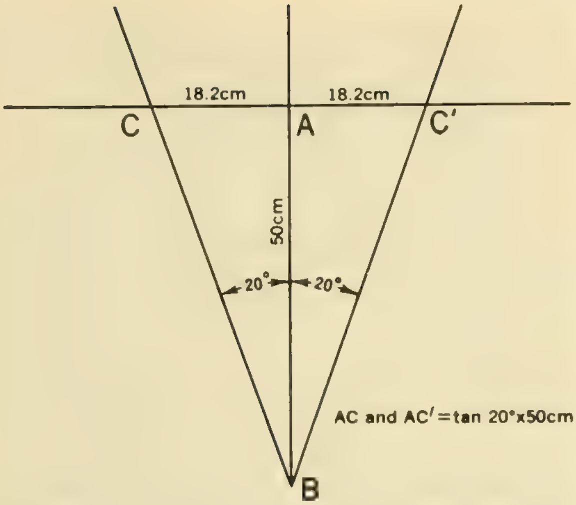


FIGURE 11.—Construction of plate to test three-arm plastic protractors.

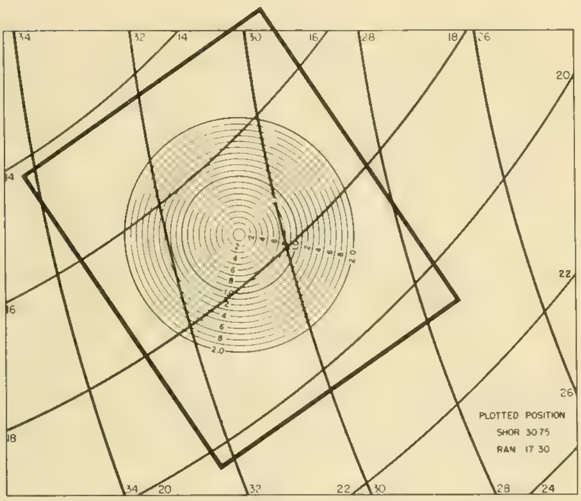


FIGURE 12.—Plotting Shoran (EPI, Raydist) positions with Odessey protractor.

Electronic Control Equipment

3–23 Electronic Position Indicator (EPI).—The Electronic Position Indicator (Fig. 13) system was developed by the Coast and Geodetic Survey after the close of World War II. It was designed primarily to control offshore surveys which were formerly controlled by Radio Acoustic Ranging, astronomic sights, and dead reckoning, and to control surveys beyond the limits of Shoran.

Detailed instructions for use and maintenance of EPI equipment are contained in Special Publication No. 265–A EPI Manual, Mark III, Model 3.

EPI is a pulse-type arcuate system which requires mobile ship equipment capable of transmitting pulses of electromagnetic energy and of measuring very small increments of time (distance); and two fixed ground stations which are capable of transmitting similar pulses accurately synchronized with those from the ship. The ship instrument measures the time for the pulses to travel from it to the ground station and return. The time intervals are measured at a rate of more than 20 times per second. For this system, the velocity of propagation of electromagnetic waves through the atmosphere is assumed to be 299,690 kilometers (186,-218 statute miles) per second. Although it is possible to fix the position of the ship at any time, it is preferable to establish a definite time interval between fixes.

3–24 EPI frequencies.—The pulse repetition rate is 41⅔ per second with a pulse length of about 60 microseconds. Radiated power from the antenna is about 10 kilowatts. The receiver bandwidth is about 85 kilocycles. The frequencies used are 1850 and 1950 kilocycles and these frequencies are shared with the standard Loran service. The frequency used should not conflict with Loran rates servicing the area. A Loran rate prefixed by the numeral 1 is operating on 1950 kilocycles, and if prefixed by the numeral 2 is operating on 1850 kilocycles. Frequency assignments should be requested from the Washington Office.

3–25 Range of EPI.—The minimum range of EPI is about 10 miles, but EPI should not be used at distances less than 15 miles. Under low static conditions, dependable measurements can be made to distances of 500 nautical miles, and to distances of 250 nautical miles when static is abnormal. Since static is always worse at night, barring local storms, it is customary to plan night operations in areas within these limits.

3–26 Accuracy of EPI.—The systematic errors of EPI equipment can be determined by calibration tests and the observed dis-

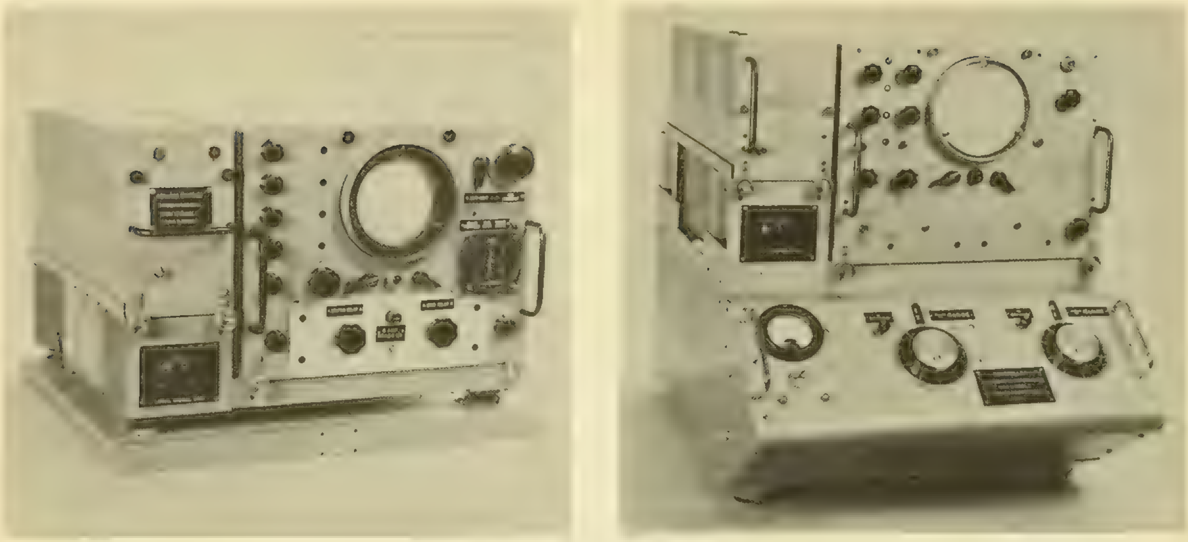


FIGURE 13.—Electronic Position Indicator Equipment; shore station on left, ship station on right.

tances corrected. Random errors are not predictable and cannot be compensated. At the ship station they may be caused by:

(a) Misalignment of local and distance pulses.

(b) Careless reading of the distance vernier and dials.

(c) Poor alignment of pulses due to incorrect gain settings.

At the shore station, they may be caused by:

(a) Poor synchronization at the time of the fix.

(b) Incorrect setting of the balanced gain.

The radial accuracy of a measured distance to a ground station is about plus or minus 100 meters. The position accuracy depends on the summation of the above errors and the angle of intersection of the distance arcs. The EPI system does not provide control suitable for plotting hydrography on scales larger than 1:100,000 (see 1–19b).

3–27 Locating the shipboard equipment and antenna.—From electrical considerations, the controller-indicator and transmitter should always be located where a good welded ground connection can be made to the ship's metal bulkhead or deck. Heavy copper braid should be run from a metal bulkhead or deck connection to the controller-indicator and connected to the chassis in the vicinity of the antenna cable input jack. A good ground here is very important since it will determine the maximum range of the instrument. The transmitter chassis must be well-grounded to a bulkhead or deck.

The controller-indicator and transmitter must always be separated by a minimum distance of 10 feet. The choice of position for the controller-indicator is most often controlled by the space that is available in the vicinity of the plotting table. When the controller-indicator is located near the plotting table, the hydrographer can supervise its operation. It also simplifies communication between the various points of operation. When the controller-indicator is remotely located, a communication system between this unit and the plotting room will be needed. Two or three feet of space all around the controller-indicator for operation and maintenance of this instrument is desirable. If the ship's power system is poorly regulated, a voltage regulator should be used.

In locating a shipboard antenna it is desirable to get as much vertical component in the antenna as possible. This is usually difficult as any wire supported vertically would be too close to a supporting mast and cause severe directional effects. The ideal practical

installation would be for a metal ship to have two masts and support a "T" type antenna halfway between them, the downlead coming to an insulated support then directly into the antenna coupling unit. The length of the downlead plus the length of the longest leg of the flat top should not be longer than 95 feet. For ships with only one mast a support should be found as high as possible some distance away from the mast to attach a guy so a modified inverted "L" antenna can be erected. The total length of the wire should not be more than 95 feet. Mutual coupling to adjacent antennas can be a serious problem. If the EPI antenna is close to another antenna that is being operated by a transmitter in the vicinity of 2 megacycles it might be impossible to get the EPI antenna to load properly. In such a case the interfering antenna should be disconnected at its transmitter and left floating while EPI is in use. When operating and calibrating EPI all antennas which are at all near the EPI antenna should be ungrounded.

3–28 Locating the ground station antenna.—The ground station EPI antenna is usually a 100-foot aluminum mast with a 100-foot radial ground plane consisting of 32 copper wires. The most important requirements are listed below:

(a) It is desirable that the ground be fairly level and clear for a distance of about 100 feet from the center of the system.

(b) While the location may be on high ground, there is no advantage in having the station elevated except when Shoran is used for calibration. In fact, other considerations make it more desirable to have the station on low ground near the water's edge.

(c) Have the station so located that the signals will not have to pass over more than a quarter of a mile of land from any direction to the service area.

(d) Where the ground wire is close to the water's edge, the wire should never be under water at any stage of the tide.

(e) The antenna should not be located near high tension wires. In damp weather such lines are capable of emitting strong interference.

(f) If possible, keep away from existing high-power radio transmitters such as a broadcast station and long-range communication stations. If there is doubt about an area in this respect, it is wise to set up a sensitive communications receiver in the area and monitor the frequencies to be used for EPI keeping in mind that the bandwidth of an EPI receiver is 85 kilocycles. Strong signals as much as 200 kilocycles away from the EPI center frequency can seriously harm distance signals from the ship unit.

3–29 EPI calibrations.—The EPI system is not self-calibrating, and the correction to observed distances must be obtained by direct comparison with known distances. Three methods of calibrating EPI equipment are described in Chapter 2 of Special Publication No. 265–A, EPI Manual. Note that when the Shoran calibration method is used, the Shoran must also be calibrated and appropriate corrections applied to observed distances before a comparison is made.

EPI equipment should be calibrated:

(a) At the beginning of each field trip.

(b) After each shutdown of equipment.

(c) Whenever a change is made in the equipment which might affect the calibration.

(d) At the end of each trip.

(e) At other times when convenient.

Calibrations should not be made until both ship and shore equipments have been in operation a minimum of 45 minutes. A record should be kept on the ship and at each shore station of all repairs, changes in equipment, or accidents which might affect the calibration (see 5–91).

It is advisable to record all EPI calibrations in a separate sounding record for each project, or each season when working on continuing projects. At the end of a season or a project, a special report on EPI corrections should be submitted and reference made to it in appropriate descriptive reports (see 7–27).

3–30 Effect of ships' heading.—As mentioned in 3–27, there is a possibility of directional effects through mutual coupling of adjacent antennas or other interference on

various compass headings. The directivity pattern for each ship installation should be determined during the first calibration tests each season and spot checks on the correction curves should be made periodically. These patterns are usually in the order of one or two microseconds; however, they may be much larger. The system of grounded and floating antennas should be the same for all periods of calibration and operation, and all antennas should be ungrounded if practicable.

3–31 Ground station personnel and communications.—The basic minimum staff of an EPI ground station is: one electronic technician and two station operators. The staff should be increased to five men if the station is to operate continuously on a 24-hour basis. A cook should be detailed to the party when the station is in a remote area and other mess facilities are not available. One man in the party should be qualified to service and maintain the portable generators. The accuracy of EPI distance measurements depends on the quality of the work done at the shore stations as well as that done by the observer at the ship station. The men assigned to an EPI station should be carefully selected from the best available personnel.

Reliable and continuous radio communications must be maintained between the ship and the shore stations if the system is to operate efficiently (see 2–26). Communication on voice modulation is satisfactory most of the time; however, when the ship is operating at a distance beyond the range of the radiophone, CW communication will be required. At least one person at the shore station should be proficient in CW radio telegraph operations under such circumstances.

3–32 EPI fixed positions.—Frequency of positions will depend on the scale of the survey. When plotting at a scale of 1:100,000 fixes at intervals of 10 to 15 minutes will suffice. When running closely-spaced lines for development of banks or other features, it may be advantageous to reduce this interval. Distances are read from the counters and range dials to the nearest 0.1 microsecond. The readings shall be recorded in the sounding record and, for convenience of the plotter, on a plotting abstract. The range dials should not be moved until the position has been plotted.

EPI positions are plotted with reference to distance circles drawn on the sheet in accordance with 5–11 and Table 9. An Odessey protractor of suitable scale is used for plotting the positions (see 3–22). When the system is operating under favorable conditions, there should be little difficulty in sounding along a prearranged line. However, at night, or near the limit of usable signals, or when atmospheric conditions are unfavorable, some difficulty may be experienced. The skywaves at night are particularly troublesome and great care is necessary to avoid use of a skywave when matching pulses. Errors of this kind are usually obvious and shall be rejected in the record book.

On some projects it is desirable to have the ground stations serve more than one ship. Half-hourly fixes can be obtained by three ships if all ship and shore station equipments are operating properly and each ship turns its transmitter off as soon as a fix is obtained. Two ships can operate on a position interval as small as 10 minutes. When multiple use of a shore station is required, a definite schedule is prearranged and each ship will turn its transmitter on 5 minutes before time for a fix. This is to allow sufficient time for the shore station to synchronize its equipment. The ship transmitter must be turned off promptly after the fix is recorded to avoid encroachment on the time allotted another ship.

When operating in this manner, it is essential that all units have the same clock time, the same transmitting frequency, and, most important of all, the same pulse rate. If the pulse rates are not exactly the same on all ships, the shore stations will have difficulty getting in synchronization in the short period of time available. In preparation for this kind of operation, the 100 KC crystal in the controller-indicator aboard one ship should be adjusted against WWV. The other ships operating in the system will ad-

just their crystals so that the transmitted signal from the first ship is stationary on the indicator scope. See section 11:204 of Special Publication 265A for information on adjustment of the crystal oscillator.

3–33 Shoran control system.—Shoran is the name given to a special type of radar system developed during World War II for the purpose of accurately fixing the position of an aircraft in flight. It was first used for control of hydrography by the Coast and Geodetic Survey in 1945. The position of a sounding vessel is obtained by measuring the elapsed time between a transmitted pulse and the return signal from two fixed stations.

A Shoran system consists of one ship equipment, designated Radio Set AN/APN–3, and two ground equipments designated Radio Set AN/CPN–2, each with all accessories such as antenna system, transmission lines, and power sources. Some ground stations now in service are designated AVQ–5G(C) and are converted AN/APN–3 equipments. A more precise type of Shoran, called Hiran, is available in limited quantities. Ship units are designated AN/APN–84, and ground units are designated AN/CPN–2A.

The following manuals must be on hand when Shoran equipment is being used:

(a) Handbook of Maintenance Instructions for Radio Set AN/CPN–2.

(b) Handbook of Maintenance Instructions for Radio Set AN/APN–3.

(c) Instruction Manual—Model AVQ–5G(C). Item (c) is a supplement to (b) and is required only when converted ship equipments are used.

Special instructions and manuals will be furnished with Hiran equipment.

3–34 Shoran installations.—The Ship Shoran unit consists of an indicator (Fig. 14), transmitter, and two small antennas. Because of the noise created by a high-speed blower in the transmitter case, the transmitter should be located in a compartment adjacent to the working area. The indicator should be mounted near the plotting table.

The ship antennas consist of two dipoles, one for receiving and one for transmitting. These are mounted as high as possible on the foremast. Ground planes for mounting the antennas are supplied and consist of a quarter-wave horizontal metal wheel mounted on a framework of aluminum. The distance between the antennas should not be less than six feet because of mutual coupling.

The MIMI (Mark 1, Model-1) Shoran antenna is a recent development which has proved satisfactory as a replacement for dipole antennas. It is omnidirectional in a horizontal plane and has elements mounted on a single metal pole. This antenna is easier to mount and has a 3 to 4 decibell gain as compared with the dipole antenna and with a smooth horizontal pattern. It may be used at the mobile or ground station; however, a reflector cannot be used with the MIMI antenna.

3–35 Shoran ground stations.—The choice of sites for the ground stations has an important bearing on the performance which can be expected of the system. The antenna elevation above sea level should be sufficient to provide line-of-sight coverage of the area to be served. There should be a minimum amount of land between the station and the service area, and there should be no obstructive upright metallic structure within a half mile on line to the service area. Sources of radio noise should be avoided, such as high voltage power lines, radar installations, and automobile ignition systems. The location should be reasonably level and clear so that the mast can be erected and guyed without difficulty.

When a reflector is used with the shore station antenna, its position must be changed from time to time as directed by the hydrographic party. The reflector is rotated from the base of the antenna by two lines attached to the reflector for that purpose. Four stakes set around the base of the tower at the cardinal points of the compass will assist the operator to orient the reflector correctly, especially when visibility is limited by fog or rain.

A shelter for the equipment is required. The generator should be housed separately. The AVQ–5G(C) requires only about 700

FIGURE 14.—Shoran ship set AN/APN-3, receiver-indicator on left, transmitter on right.

watts of power as compared to 1600 watts for other ground station equipments. However, these converted systems can serve only 4 survey units simultaneously, whereas the AN/CPN-2 or 2A can serve a maximum of 20 units.

Shoran antennas corrode rapidly when the priming coat is scratched. Application of an acrylic plastic will prevent corrosion for a considerable period. It is advisable to spray nuts and bolts and the coaxial connector as well as the scratched areas. The coaxial connector should be packed with Dow-Corning compound–DC 4 and taped.

3–36 Operation of Shoran.—The position of a survey vessel can be determined at any instant by measuring and plotting the distance to two known points. The ship transmits radio waves, or pulses, alternately on frequencies of about 230 and 250 megacycles. The ground station receives the signal, and, after a short delay, triggers a transmitter which returns the signal to the ship on a frequency of about 310 megacycles. The ship operator matches the returning pulses with a fixed index, thus automatically converting the elapsed time for the round trip to distances in statute miles. These distances are read from dials to the nearest .001 statute mile. In addition to the operator of the ship equipment, one man must be continuously on duty at each shore station while the equipment is in operation.

3–37 Accuracy and range of Shoran.—The radial accuracy of a measured distance from any one ground station is about plus or minus 75 feet. The errors in observed distances vary with distance and signal intensity. Some distance errors may be determined and compensated by careful and repeated calibrations. The correction is not a constant. It starts as a small value near the

ground station and increases nearly linearly with distance up to about the refractive line-of-sight. After this the correction increases nearly exponentially until the signal disappears. A discussion of sources of Shoran errors is contained in Coast and Geodetic Survey Journal, Vol. 6, pages 23–31.

Theoretically, the range of Shoran is the line-of-sight distance between antennas and is expressed in the formula:

$$D=K(\sqrt{H}+\sqrt{h})$$

where D= Distance in statute miles
H= Elevation of [illegible] antenna in feet
h= Elevation of ship antenna in feet
K= a constant

For line-of-sight computations K=1.32; however, certain effects of refraction due to atmospheric conditions permit increasing the constant to 1.42 as being a practical value. It is possible to receive usable pulses at much greater distances than those computed by this formula, and the constant in such cases approaches the value 2.0. Shoran should seldom, if ever, be used beyond the limits imposed by K=1.42 because corrections to Shoran distance measurements become uncertain at greater ranges. It should be noted that the elevations of the respective antennas have added effects. When relatively low antennas are used, such as those on launches, the maximum value of K decreases from 2.0 to about 1.7.

3–38 Shoran calibrations.—As previously stated, the errors in observed Shoran distances vary with distance and signal intensity. The amount of these errors must be determined by comparison of observed distances with known distances. Each ship and launch equipment must be calibrated with each ground station used in a survey (see 5–44). When an APN–3 has been calibrated aboard ship and later transferred to a launch the equipment must be recalibrated. When a ground station is moved to a new location, the old calibration values shall not be used and recalibration is necessary.

An adequate number of calibrations carefully made are essential to avoid complications in plotting and verifying the smooth sheet.

Before making a correction calibration, the following preparatory procedures shall be followed:

(a) Allow all equipments in the system to warm up for about one hour prior to calibration.

(b) Accomplish a calibration adjustment, which is a comparison and adjustment of the ship crystal oscillator frequency with the more standard frequency of the CPN–2 ground station crystal oscillators.

(c) Adjust the line voltage to the proper value. (See Manuals).

(d) Make a zero check and record the value for reference.

(e) Notify the ground stations that correction calibrations are to be made and state the direction antennas are to be pointed if reflectors are used.

(f) Adjust the receiver gain to a value where additional gain does not produce a change in the shape or position of the ground station signal.

When notified that a correction calibration is to be made, the ground station operator shall proceed as follows:

(a) Point the antenna as directed.

(b) Adjust the line voltage to the proper value.

(c) Standardize the ground station delay.

(d) Adjust the receiver gain to the proper value consistent with the ship signal strength.

3–39 Methods of calibrating Shoran.—The most commonly used method of calibrating Shoran is to compare Shoran distances with distances determined by a three-point fix. When this method is used, the fix must be very strong, using triangulation stations where possible, and a check angle should be observed. The comparison is made by plotting the fix on a metal-mounted sheet on which the signals and Shoran circles have been plotted. The correct distances to the Shoran stations as determined by the sextant fix are scaled off with an Odessey protractor and the differences between these

distances and observed Shoran distances are the corrections to be applied to subsequent Shoran readings *at that distance.* A zero check shall be recorded immediately following the calibration tests.

The range and angle method is often used and is somewhat more precise than the three-point fix method. When this method is used, the ship proceeds along a sensitive range at slow speed until a predetermined sextant angle to right or left of the range is closed. Shoran distances are observed at that instant and compared with distances to the ground stations which have been computed in advance. The differences between observed and computed distances are the corrections to be applied for Shoran readings *at that distance* and for a particular zero check reading.

It is sometimes possible to bring a launch or small vessel alongside a pier, piling, beacon, or other point whose exact position is known. The Shoran distances can be compared and the correction determined.

3–40 Distribution of calibrations.—If possible, calibrations shall be obtained near minimum and near maximum ranges used in the survey. Intermediate calibrations are desirable to help define the correction curve. Care should be exercised in selecting calibration sites to avoid reflections from shoreline or other objects.

It is advantageous to have one or more check points in the area at which daily comparisons may be made, as in the range system of calibrating. Fixed objects such as beacons or piling are particularly useful as check points for launch hydrographic parties.

3–41 Statistical method of calibration.—When circumstances prevent calibrating from near minimum to maximum ranges used, a correction curve may be derived by computation as a last resort. An extensive study of Shoran corrections has revealed that:

(a) The Shoran distance-correction curve is nearly linear except when close to or far from the ground station.

(b) The slope of the Shoran distance-correction curve is nearly the same for all Shoran instruments when antenna heights are equal or nearly so.

(c) For any ground station height within the range normally used for hydrographic surveys, the slope of the distance-correction curve is most sensitive to the antenna height on the mobile unit.

The correction curves for various equipments operating under identical conditions will be nearly parallel but will seldom coincide. The curves will have negative slope and will increase negatively at a uniform rate with increasing distance from the ground station. The rate of increases is, in some respects, a function of ship antenna height. For purposes of deriving distance correction curves, ship antenna heights may be classified as low or high as follows:

(a) Low ship antennas are those under 40 feet and the slope of the curve is 0.003 mile per mile (statute).

(b) High ship antennas are those in excess of 40 feet and have a slope rate 0.0018 mile per mile.

To derive a correction curve, it is necessary to determine the correction at one or more distances by methods previously described. From these points the curve may be extended as a straight line by using the values in (a) or (b) above. To aid in applying the correction when plotting, the curve may be translated to a tabular form. Values in the table should be distances from the ground station corresponding to a correction change of 0.005 statute mile.

3–42 Recording calibrations.—All Shoran calibrations shall be recorded in the sounding record for the survey, or in a special record reserved for that purpose. The record shall include the number identifying each ship or ground station equipment involved in the calibration (see 5–91).

When a number of correction measurements are made at the same location, a plot of the correction against time should be made to detect any indication of equipment degradation. When measurements over a wide distance range are made, a plot should

be made of the correction with respect to distance from the ground station.

3–43 Shoran zero set.—Distances to ground stations are obtained by matching returning pulses with a reference pulse or marker. The zero set is an adjustment which changes the time position of the reference marker, and has the effect of changing both the rate and drift zero check values. The zero set is thus used to make the zero checks some convenient value or to reduce the station corrections to a minimum.

If a zero check reading (3–44) changes more than 0.005 mile, from its normal value either by a sudden jump or slow drift, it should be considered as evidence of instability in the ship set. The set should be inspected by a technician, a new calibration should be made at the earliest convenient time, and the zero set adjusted if necessary.

3–44 Shoran zero check.—The zero check measures the time relation between the zero of the distance measuring scales and the marker pulse. Since it is possible for a drift to occur in the distance measuring scales, the zero check is used to detect any such shift. This is the method of observing the stability of the timing relationship within the ship equipment.

A zero check shall be observed and recorded immediately before and after a distance-correction calibration, at the beginning of each day's work, and at least once each hour while hydrography is in progress (see 5–42).

3–45 Frequency comparison.—At the beginning of each season and once every two months thereafter, a WWV or WWVH frequency comparison shall be made for all CPN–2 and CPN–2A ground stations and for all ship stations (CPN–3) that use AVQ ground stations. It is good practice to make these comparisons more frequently than the above prescribed minimum.

3–46 Shoran report.—In addition to the continuous study of Shoran corrections carried on during the progress of a survey, a comprehensive analysis and compilation of calibrations must be made at the end of the season or on completion of a project. Tables of distance corrections shall be compiled for correction of observed distances. A copy of the table should be included in the descriptive report to accompany each Shoran- controlled survey (see 7–9) and reference shall be made to the Special Report on Shoran Corrections.

The calibration sheet, details of computations, and similar data should not be forwarded with the report. The methods used should be explained and any abnormal corrections specifically mentioned. In order that the verifier may have a complete picture of the calibration program, the report shall include a listing, by geographic coordinates, of all calibration points used and the dates when calibrations were made at each point. (see 7–27).

3–47 Precautions when using Shoran.—If properly used, Shoran provides an excellent method of controlling hydrographic surveys. The following is a partial list of precautions which should be taken to avoid unnecessary complexities in smooth plotting and verifying a hydrographic survey:

(a) Make frequent calibrations to determine distance corrections.

(b) Establish check points for repeat observations.

(c) Make calibrations over the full range used.

(d) If the signals pass over intervening land they will be attenuated and special calibrations in such areas are required.

(e) Avoid use of Shoran beyond limits imposed by the constant $K=1.42$.

(f) Watch for reflections when the signal passes close to cliffs or bluffs.

(g) Ground station personnel must be alert and conscientious. Assign this duty to the best qualified men available.

(h) Voltage at all stations should be maintained at 115 volts. An appreciable drop in voltage will decrease signal intensity and increase distance corrections.

(i) If reflectors are used at the ground stations they should be properly pointed to provide maximum signal intensity.

(j) Any radical change of the zero check is an indication of trouble in the system. A loose antenna connector will cause such a change. Consult a technician to see if other factors are causing the change.

(k) If practicable, observe an occasional three-point fix for comparison with a corrected Shoran fix. This may disclose unsuspected errors.

(l) Adjust the receiver gain as necessary to retain the shape of the ground station signal.

(m) Great care should be taken to prevent any damage to the coaxial cables, both ashore and afloat. If these cables are crimped, bent sharply, or the insulation broken, water will enter the cable. This moisture can ruin the cable, rendering the Shoran useless, and this particular type of equipment failure is difficult to find.

3–48 Raydist control systems.—Raydist is a radio system in which phases of two continuous-wave signals are compared. A number of designs of the Raydist system permits presentation of position data in various forms: range, elliptical, and hyperbolic or combinations of two of them. The range or circular system is used by the Coast and Geodetic Survey. In this system the distance to the R_1 station is measured directly, however the line-of-position from the R_2 station is elliptical and is converted mechanically to a range distance and presented in this form.

Instructions for servicing and operating Raydist equipment are contained in manuals furnished by the manufacturer and are supplemented by additional instructions and diagrams compiled in the Electronics Laboratory.

The use of Raydist for control of hydrography has been limited to one major project at the time this is written. The following instructions are based on this experience and are subject to change with further developments.

3–49 Raydist operating principles.—The determination of distance by the Raydist

FIGURE 15.—D. M. Raydist equipment for mobile station.

system is based on the measurement of a phase difference in two radio signals, one emanating from a transmitter aboard ship and the other from a transmitter at one of two fixed stations ashore. In order to obtain the distances to both ground stations it is necessary to measure the phase difference at three places—aboard ship and at each ground station.

Four radio transmitters and frequencies are required to operate the system—the two distance-measuring frequencies mentioned above and two others to transmit information to the ship concerning the phase relationship at each ground station. The latter frequencies do not enter into the determination of distance, however, interference on any of the four frequencies will affect operation of the lane counters in the phase meter. The ground station where the distance-measuring transmitter is located is referred to as the R_1 or "Red" station, and the other the R_2 or "Green" station.

Because it is difficult to measure phase directly at the radio frequencies used, a technique known as heterodyning is employed. If two radio signals are fed into a detector, the issuing signals will have a frequency that is equal to the difference between those of the entering signals and will portray the phase changes that take place between them. In Raydist the entering signals are separated by 400 cycles, and after detection this frequency is fed into a phasemeter. The heterodyne technique permits the measurement of high frequency signals to be made at a low frequency without sacrifice of accuracy.

3–50 Distance measurements.—The distance from the ship to the Red station is measured by comparing the phase of the transmitter on the ship with the phase of the transmitter at the Red station. The distance is measured in terms of half-wave lengths of frequency between the two stations. These half-wave lengths are called "lanes", and for presently assigned frequencies, the lanes are about 45 meters or 150 feet wide. The width of a lane is a function of the frequency of the transmitter at the mobile station and is expressed by the formula $L=V/2F$ in which $L=$ lane width; $V=$velocity of propagation of radio wave or 983,167,315 feet per second, and $F=$ frequency of the transmitter. When drawing distance circles on the survey sheet the value of L is assumed to be the same for both the Red and Green stations. However, the distances to the Green stations are subject to correction because of the elliptical system employed. Computation of this correction is described in 3–56.

3–51 Installation aboard ship.—Three whip antennas are required aboard ship, one for transmitting distance measuring signals, one for receiving the distance measuring signals, and one for receiving information from the ground stations. The equipment aboard ship includes:

(a) **Transmitter**—A 100-watt unit for transmitting the distance-measuring signal.

(b) **Navigator**—Containing three receivers.

(c) **Monitor**—Used to measure the frequency of the 400 cycle signals and to check the audio tones received from various points in the system.

(d) **Phasemeter**—Registers the lane count on dials to the nearest 0.01 lane.

(e) **Brush Recorder**—Records in ink on a special tape the lane changes as shown on the phasemeter dials.

(f) **Power Supply**—Converts the main power supply to proper voltage for use in the equipment.

The transmitter and power supply may be located in any convenient place, but the other units should be mounted near the plotting table. The equipment required at the mobile station, except the antennas, is shown in Figure 15.

It is difficult for one person to read both phasemeter dials simultaneously, especially when both distances are changing rapidly. For this and other reasons, it is desirable to attach a recorder which will print phasemeter dial readings on a tape at any instant. (Fig. 16) The printer is not a part of the Raydist equipment.

A partially transistorized 10-watt Raydist

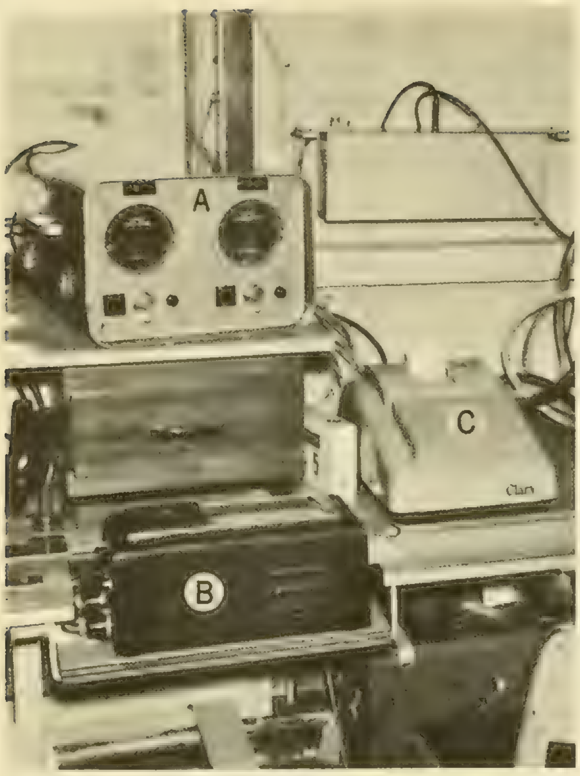


FIGURE 16.—A. Raydist phasemeter. B. Brush recorder. C. Digital printer.

system is also available and can be used in launches over a limited distance estimated to be about 35 miles. Two whip antennas may be used, or if duplexing techniques are used only one antenna will be required. The two systems are compatible, that is, any station in the portable system can be substituted for a like station in the D.M. system.

Two survey vessels can be served by one pair of ground stations. The limitation on multiple use has not been determined; however, it may be possible for 3 or 4 mobile stations to operate successfully in conjunction with one pair of ground stations. Mobile stations should not operate simultaneously at distances less than ¼ mile from each other.

3–52 Installation at Red ground station.— Two transmitters and a dual receiver are required at the Red station (Fig. 17). One transmitter emits a distance-measuring signal on a frequency which is 200 cycles less than half the frequency of the mobile station transmitter. The second transmitter provides a carrier frequency for relaying information.

The antenna system at the station depends on the range at which the system is to be used. When the 10-watt system is used, or if the 100-watt system is limited to a maximum range of about 50 miles, 35-foot whip antennas may be used. A radial ground plane is required at each antenna having a radius approximately equal to the antenna height.

When maximum distance is desired, three 100-foot tower antennas with 100-foot radial ground planes must be used. If duplexing techniques are used, only two towers are required. As a general rule, duplexing of antennas at any station will reduce signal strength and effective range of the system. The antennas at ground stations should always be approximately 250 feet apart. At the Red station one antenna is required to transmit the C–W signal, one to transmit the carrier frequency signal and one to receive the distance measuring signals. When the antennas are duplexed the latter antenna is placed atop the C–W antenna. The three towers are set up in a straight line with antennas involved in distance-measuring being symmetrical with respect to the point or station from which distances are measured, and the carrier frequency at the center tower over the station. The three-tower system requires that a correction be applied to the Green station distances as described in 3–56. This correction is avoided when duplexed antennas are used and they are placed over the station.

3–53 Installation at the Green station.— One receiver and one transmitter are required at the Green station. Two 100-foot tower antennas with ground planes are required for maximum range. The antenna which receives the distance-measuring signals should be placed on the marked station from which distances are measured. The second antenna should be about 250 feet distant and is used for transmitting the carrier

PHOTO BY HASTINGS-RAYDIST

FIGURE 17.—Raydist Red and Green shore station equipment.

frequency. Whip antennas may be used as in 3–52, or the antennas may be duplexed.

3–54 **Power sources.**—Electric power for operation of ground stations, approximatly 3 kilowatts, may be obtained from commercial sources, 115–120 volt—60 cps, or from portable generators at the stations. If commercial sources are used, it is advisable to have a portable generator at each station ready for emergency use in event of a power failure.

3–55 **Range and accuracy of Raydist.**—The maximum range at which the D.M. Raydist can be used satisfactorily for control of hydrography has not been determined through experience. Strong signals from the Green station have been received at a distance of 225 nautical miles. At the same time signals from the Red station, which was 175 miles distant, were not usable. In this instance the antennas at the Red station were duplexed and signals were not as strong as they were with the three-tower system.

Raydist signals are subject to interference by skywaves at night if the strength of the skywave signal is greater than that of the groundwave. Skywave contamination may be expected at distances greater than 100 miles. This applies to the distance between ground stations as well as the distance of the mobile station from either ground station. Atmospheric conditions will also affect Raydist. Electrical storms near any station or between stations and rain static at any station will frequently affect the lane count. Strong radio communication signals close to a frequency used in the system may interfere with its operation, especially if some skywave contamination is present.

Interference with Raydist signals has the effect of causing the phasemeter dials to show a gain or loss of lanes. These will also show on the brush recorder tape. By keeping a close watch on the tape it is possible to detect the gains or losses. The observed values can be corrected accordingly. Gains or losses will be in whole lanes, not fractions of a lane. Skywave interference will cause the phasemeter dials to oscillate through an arc which increases with the strength of the wave. A continuous strong skywave signal will cause such erratic operation that it will be impossible to keep track of the lane count and the sounding line must be broken.

Raydist distance measurements are accurate to a few tenths of a lane and accuracy does not deteriorate with distance so long as usable signals can be received. Errors in distance measurements remain constant at any distance except as noted in 3–56. The system does not provide a method of lane

identification. If the lane count is lost it is necessary to return to a known point and reset the counters before continuing hydrography.

3–56 Corrections to Raydist measurements.—As stated in 3–50 the R_2 lane width is assumed to be the same as that of the R_1 lane for drawing distance arcs from the ground stations. The R_2 distance and the width of the R_2 lane are complicated by the fact that an elliptical method is used to measure the sum of the R_1 and R_2 distances and then the R_1 distance is subtracted in the phasemeter. The correction is a function of the cycle differences in two signals, usually 400 cps.

For example, if a frequency of 3280 KC is used at the mobile transmitter, a frequency of 1639.8 KC will be used at the Red station distance measuring (C–W) transmitter. The R_1 lane width will be 149.87307 feet, which is obtained by dividing 983,167,315 feet by 3280 and then dividing the resulting wave length by 2. In this instance the

R_2 distance in feet$=149.87307\psi_G+0.00012(R_1-R_2)$ in which

ψ_G=Phasemeter reading for the R_2 station in lanes.

R_1=Distance to Red station in feet.

R_2=Distance to Green station in feet.

The R_2 distance in the sum of the R_1 and R_2 distances is measured directly, but by an effective frequency of 3280.400 KC which is 400 cycles larger than the frequency used to compute the lane width. The 3280 KC frequency from the mobile transmitter is returned to the ship on a frequency of 3280.400 KC. The factor 0.00012 is the quotient when 400 is divided by 3,280,000.

The above formula is difficult to use in the field but it can be reduced to a formula by which a correction to R_2 distances can be computed when the mobile station moves from the point where the dials are set. The correction formula is:

R_2 correction (in lanes) $= +0.00012[(\psi R''-\psi R')-(\psi_G''-\psi'_G)]$ wherein the subscripts R and G indicate R_1 (Red) and R_2 (Green) phasemeter dial readings respectively and $''$ and $'$ indicate readings at the calibration point and the point for which correction is desired, respectively. The formula is used with the R_2 lane width the same as that of the R_1 lane and no correction is applied when the R_2 dial is set at the calibration point.

A second correction to R_2 distances is required if three antennas are used at the Red station. If antennas are duplexed at the Red station this correction is eliminated. The arrangement of the three-antenna system is described in 3–52. The correction to R_2 distances is related to the location of the C–W (distance measuring) transmitter with respect to the center of the antenna system at the Red station. The correction is expressed in the formula:

Correction to R_2 distance (in lanes)$=d$ cosine $(A_s - A_t)$ in which d is the distance in lanes from the Red station center to the C–W transmitter antenna, A_s is the azimuth of the mobile unit from the Red station center, and A_t is the azimuth of the C–W transmitter antenna from the Red station center (Fig. 18).

The point of origin for measurement of distances on a ship using three antennas is related to antenna locations and may be some distance from the location of the echo sounder transducers, which, on most ships, are located within a few frames of the foremast. With the distance-measuring signal antenna at the main mast and the receiving antennas at the foremast, the point of origin for the R_1 distance is midway between the masts (Fig. 19). The origin of the R_2 distance cannot be defined as a single point because of the elliptical configuration, but for this computation is assumed to be at the main mast. The R_1 and R_2 distances may be reduced to the foremast by applying a lane correction derived from the formulas:

$$C_1=\tfrac{1}{2}D \text{ cosine } (SH-Ar)$$
$$C_2=\tfrac{1}{2}D \text{ cosine } (SH-Ar) - D \text{ cosine } (SH-Ag)$$

Where

C_1=correction to R_1 distances in lanes

C_2=correction to R_2 distances in lanes

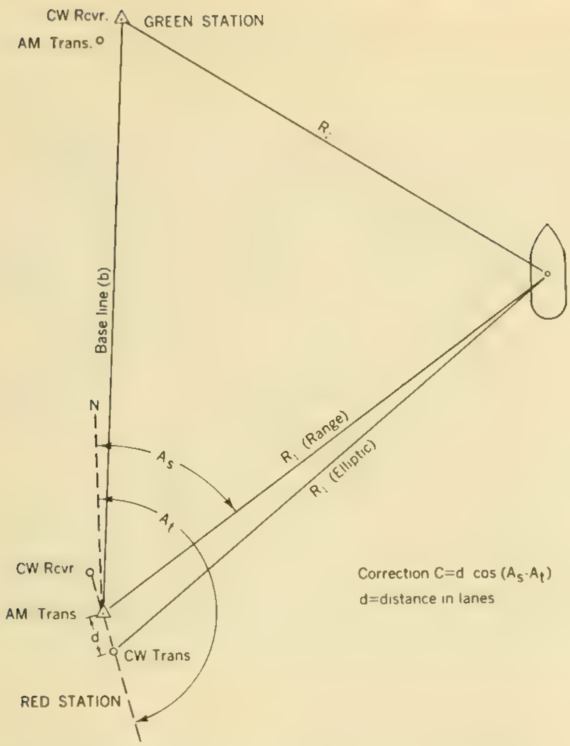


FIGURE 18.—Corrections to Raydist distances when three-tower antenna system is used at the red station.

D=distance in lanes between masts
SH=ship's head (true)
Ar=direction to the Red station
Ag=direction to the Green station

To apply the R_2 correction with respect to all variables would be laborious. When the correction is applied, a table of corrections to the nearest 0.2 lane should be used, and small course changes required to follow the guide line may be ignored. When the antennas are duplexed at the approximate location of the transducers both R_1 and R_2 corrections are eliminated.

3–57 Raydist brush recorder.—The brush recorder as used in the Raydist system is an instrument for continuously recording the lane changes as shown on the phasemeter dials. An inked line is drawn on a tape for each dial (Fig. 20). The slope of the line shows whether the lane count is increasing or decreasing and the rate of change. It is especially useful when interference of any

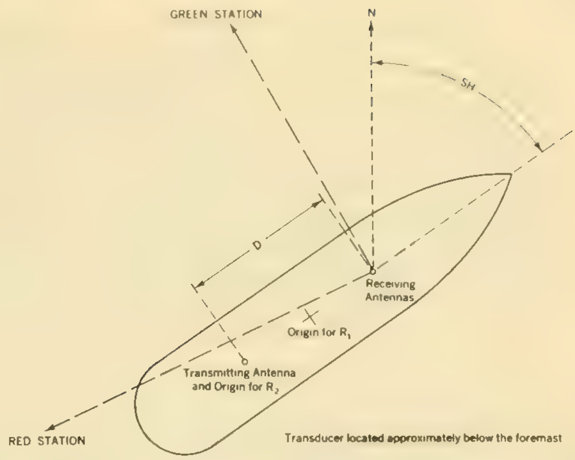


FIGURE 19.—Corrections to Raydist distances to reduce observed positions to location of transducers.

kind causes the phasemeter to operate erratically.

During hydrographic operations one man is stationed at the brush recorder. The lane count is marked at the calibration site when the phasemeter dials are set, thereafter every fifth or tenth lane is numbered. Each position is marked and numbered on the tape. Frequent comparison between the brush recorder and the phasemeter is necessary to detect any gain or loss of lane count.

3–58 Setting phasemeter dials.—Unlike other electronic instruments for determining position, the Raydist phasemeter dials must be set correctly at a known position, and if the lane count is lost it is necessary to return to a known position to reset them. Once the dials have been correctly set, the equipment will automatically keep track of position unless there is serious interference with radio signals or a failure in the equipment.

The dials may be correctly set, or the errors of the dial readings determined by one of several methods: (a) by three-point sextant fix plotted on an aluminum-mounted calibration sheet of appropriate scale; (b) at a fixed object of known position such as a pile, beacon, or wharf; (c) by circling a buoy of known position; or (d) when distance arcs curve very slowly by running along a distance arc as determined by a true bearing to a buoy or a fixed object.

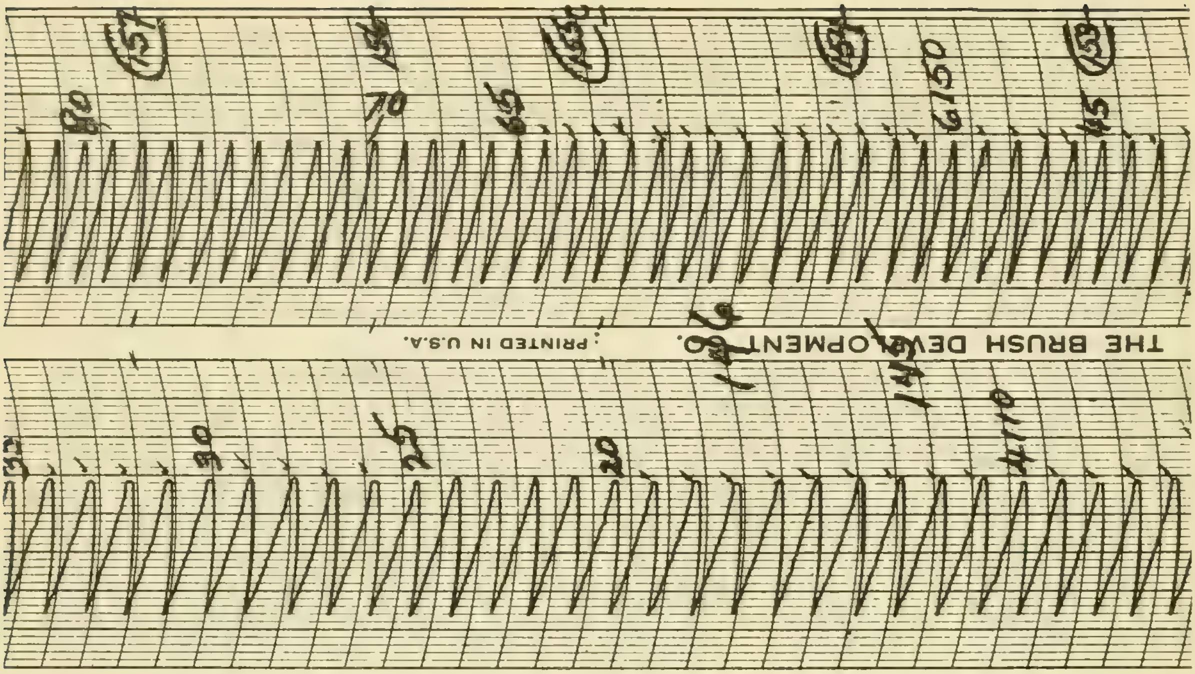


FIGURE 20.—Typical record from Raydist brush recorder.

The dials should be set to approximately correct values first when approaching the calibration point. The amount of the dial reading errors should then be determined by one of the above methods. If it is necessary to reset the dials, a recalibration is required. Since movement of the R_1 dial will sometimes affect the R_2 dial, the R_1 dial should always be set first. Signals may be attenuated when passing over land. Therefore the calibrations should be made under conditions which will prevail while hydrography is in progress.

When operating close to the Red station the carrier signal from that station may be so strong that it will feed through the filter in the Green station circuit causing the automatic volume control to operate and blank out the signal from the Green station. Under such conditions the percentage of modulation at the Red station must be reduced to a level which will not cause interference in the other circuit. The modulation at the Red station can be increased in several steps as the ship proceeds away from the station.

3–59 Three-point fix calibrations.—When the three-point sextant fix method is used, the fix should be as strong as possible and a check angle observed (see 3–39). At least three comparisons should be made after the dials have been correctly set. The observed dial readings are corrected for ship's head, if necessary, the R_2 dial reading is corrected for placement of the Red station C–W transmitter, if applicable, and the differences between these values and the scaled values represent dial corrections at that point. The three comparisons should agree within a few tenths of a lane.

3–60 Buoy method of calibration.—Where the area to be surveyed is distant from a place where the three-point fix or other accurate method of calibrating can be used, and, if the depth of water permits, it is advisable to establish one or more buoys near by which can be used as check points or for calibration if the occasion arises. The buoys should be securely anchored with a scope of about 1.5 to 1. The position of the anchor must be determined. When calibrating at a buoy, proper allowance must be made for scope of the anchor cable and direction of

the current. If calibration cannot be effected alongside the buoy, one of the following methods may be used:

If the distance circles curve very slowly, calibration may be effected by circling at slow speed close to the buoy. Scale the approximate azimuth from the ship to the buoy along the distance arcs through the corrected buoy position. Read the phasemeter dials as the ship crosses the distance arcs as shown by pelorus bearings. Correct the observed values as above and compare with the buoy distance arcs. The ship will cross each arc twice in one complete circle. If the two values do not check within a few tenths of a lane, repeat the observations until a check is obtained on opposite headings.

While stopped and drifting near the buoy observe Raydist distances, true bearing to the buoy, and a range finder distance or depression angle to the buoy simultaneously. Apply ship's head corrections and correct R_2 distance if three-antenna system is used at the Red station. Scale off the distances corresponding to the position determined by the distance and bearing to the buoy and compare them with corrected observed distances. The calibration sheet should be on a scale larger than that of the survey sheet. At least three comparisons should be made at various positions with respect to the buoy, and the mean used for subsequent corrections.

3–61 Calibration records and report.—All calibrations and checks on calibrations shall be recorded in the sounding volumes or in a separate volume used exclusively for this purpose. The corrections should be shown on the plotting abstracts. All gains or losses in lanes shall be noted on the abstract and in the sounding volume as they occur, and the time noted.

A table of corrections shall be compiled and submitted with a special report on Raydist corrections at the end of each season or project (see 7–27). A copy of the correction tables for each survey sheet shall be included in the Descriptive Report to accompany it, and reference shall be made to the special report (see 7–9).

3–62 I.H.B. Special Publication No. 39.—The electronic equipment used by the Coast and Geodetic Survey has been briefly described in the preceding paragraphs. For a more complete discussion of these and other radio aids used in hydrographic surveying, see Special Publication No. 39, Radio Aids to Marine Navigation and Hydrography, published by the International Hydrographic Bureau in July 1955.

Depth-finding Equipment and Instruments

3–63 Standard depth-finding equipment.—All soundings for hydrographic surveys shall be obtained by one of the following: sounding pole, leadline, wire sounding machine, 808 type Fathometer, EDO 255 echo sounder, or the EDO 185 (often referred to by military designation UQN) echo sounder with or without a Precision Depth Recorder attached (see 1–35). Other types of echo sounders or sounding equipment shall not be used for hydrography except by specific authority of the Director. Clearances over obstructions, when required, shall be determined by Wire Drag methods as described in Publication 20–1.

3–64 Sounding pole.—Shallow depths over an extensive flat area in protected waters can be measured more easily and accurately with a sounding pole than with a leadline and a pole shall be used in areas too shoal for echo sounders. The soundings are read to the nearest half-foot, but are limited to depths not exceeding 12 feet. The sounding pole is seldom used in general depths greater than 6 feet except to provide supplemental soundings to assist in interpretation of fathograms when sounding in areas where grass or other vegetation may obscure the bottom trace.

The sounding pole is a 15-foot length of 1½ inch round lumber, capped with a metal shoe at each end which may be weighted to hasten sinking. Any convenient system of marking which is symmetrical toward both ends and minimizes errors may be used. The following system is satisfactory:

Mark each foot and half-foot permanently

by a small notch cut in the pole. Paint the entire pole white, and the spaces between the 2- and 3-, the 7- and 8- and the 12- and 13-foot marks black. Other foot marks are indicated by ½-inch colored bands, red at the 5- and 10-foot marks, and black at the 1-, 4-, 6-, 9-, 11-, and 14-foot marks. Half-foot marks are ¼-inch bands, white where the pole is black, and vice versa.

3–65 Leadline.—Portable echo sounders have replaced the leadline as the principal instrument for obtaining soundings in relatively shoal water. Nevertheless, every unit engaged in hydrographic surveys where the general depths are less than 20 fathoms should have one or more leadlines properly marked and calibrated. Leadlines are required to search for, or confirm, the least depths on shoals and sunken rocks; to confirm echo soundings in kelp or grass; to obtain bottom samples; to obtain vertical cast comparisons with echo soundings; and are occasionally used when making temperature and salinity observations from a launch.

The Coast and Geodetic Survey has adopted, as standard leadline material, mahogany-colored tiller rope with a phosphor-bronze wire center, of six strands of seven wires each, No. 33–B. and S. gage. The wire core should not break with prolonged flexing. The rope is size No. 8, about one-quarter inch in diameter made of solid-braided long-staple cotton, and water-proofed. The braid should be tight so that broken wire strands are less likely to protrude through the covering to injure the leadman's hands. The Washington Office will furnish this material upon requisition.

3–66 Marking leadlines.—A leadline should be from 15 to 30 fathoms in length, depending on the depths in which it will likely be used and whether it is intended for use on a small boat or survey ship.

Each leadline should be identified by a consecutive number stamped on a metal disk attached at the inboard end of the line at the time of graduation. This number should be retained throughout the life of the leadline or until it is necessary to re-mark it.

The braided covering of a leadline tends to shrink with use when wet. When this occurs, the wire core eventually buckles, and strands break and are likely to protrude through the covering and injure the leadman's hands. This can be prevented by the following preseasoning before it is marked:

A leadline is prepared for use by soaking it in salt water for 24 hours. Then while wet it should be laid out where the cotton covering can be worked along the wire by hand until about a foot or so of the wire for each 10 fathoms protrudes from the covering. This is a tedious proceeding, several men have to cooperate, the covering can be pushed back only a few inches at a time, and this length of slack has to be pushed nearly the full length of the line before another few inches can be started. The excess wire is cut off. Experience has proved that a leadline so prepared, if the covering is worked back the correct amount, will maintain an almost constant length in future use. The covering must not be worked back too far or it will form bulges along the wire.

After the above preparation, the line should be dried under considerable tension and then soaked again for another 24 hours. A leadline should never be boiled as this removes the waterproofing with which the covering is impregnated.

After the lead has been attached, the line while still wet should be placed under a tension equal to the weight of the lead while it is being graduated. If temporarily marked at this time the permanent marks can be seized on afterwards.

The marks on a new leadline may be laid off with a tape, but the most convenient arrangement, and one which will be needed later for leadline vertification, is to mark the correct distances permanently with copper tacks on the deck of the ship, or on a wharf if the survey party is based at a shore station.

Two units of measure, the fathom and the foot, are used by the Coast and Geodetic Survey for the measurement of depths, but the two units are not co-mingled on the same leadline. One system of marking utilizes feet

only and the other system fathoms and tenths of fathoms. Every survey party that has occasion to use both depth units in accordance with the instructions in this Manual shall be equipped with at least one leadline marked in each unit.

Leadlines in fathoms shall be marked as follows:

Fathoms	*Marks*
1, 11, 21	One strip of leather.
2, 12, 22	Two strips of leather.
3, 13, 23	Blue bunting.
4, 14, 24	Two strips of leather secured in the middle (so that two ends point upward and two downward).
5, 15, 25	White bunting.
6, 16	White cord with one knot.
7, 17	Red bunting.
8, 18	Three strips of leather.
9, 19	Yellow bunting.
10	Leather with one hole.
20	Leather with two holes.

Between the fathom marks intermediate marks shall be placed, by which fractions of a fathom can be read in tenths. Each half-fathom (0.5) shall be marked by a seizing of black thread and each even tenth-fathom (0.2, 0.4, 0.6, and 0.8) by a seizing of white thread, the odd tenths being estimated.

All fathom marks extend 2 inches from the leadline. All the leather marks should be made in one piece, the strips, about ¼-inch in width, being slit in the free end of the mark. The bunting marks are made by folding a piece of bunting to a size about ⅝-inch wide by 5 inches long; the length of folded bunting is then folded once in the middle and secured to the leadline so the folded end is free.

Waxed linen thread should be used to secure the marks to the leadline. Marks should be secured to the line so that there is no possibility of their slipping, but the thread should never be inserted through the braided covering of the line. This is unnecessary if the marks are properly secured and it is almost impossible without mutilating either the covering or the stranded wire core. All marks should be secured so that their free ends are up when sounding except 4-, 14-, and 24-fathom marks. Marks so secured will tend to stand out more from the line when it is vertical.

The toggle which the leadman grasps when heaving the lead may be lashed on the leadline or secured in a clove hitch of the line. In the latter case the toggle must be secured before the leadline is graduated.

The lead to be used with the line, likewise, must be attached while the line is being graduated.

Leadlines in feet shall be marked as follows:

Feet	*Marks*
2, 12, 22, etc.	Red bunting.
4, 14, 24, etc.	White bunting.
6, 16, 26, etc.	Blue bunting.
8, 18, 28, etc.	Yellow bunting.
10, 60, 110	One strip of leather.
20, 70, 120	Two strips of leather.
30, 80, 130	Leather with two holes.
40, 90, 140	Leather with one hole.
50	Star-shaped leather.
100	Star-shaped leather with one hole.

The intermediate odd feet (1, 3, 5, 7, 9, etc.) shall be marked by white seizings. The leathers marking the 10-foot multiples should be identical in size with the fathom marks used on a line marked in fathoms. The bunting marks identifying the intermediate even feet should be slightly smaller in size.

3–67 Verification of leadlines.—Leadlines used for sounding should be compared with a standard at the beginning of a season and at frequent intervals thereafter depending on the extent of their use. The leadline should be wet and under a tension equal to the weight of the attached lead in water when tested.

Rubber Stamp No. 35, Leadline Comparison, shall be used in recording results of the comparison in the sounding record and shall be recorded at the beginning or end of the day's work (see 5–93 and 103). Where the leadline is found to be correct, a statement to that effect is sufficient. Where it is found to be incorrect, the results of the comparison shall be entered for each fathom, or for each five feet for a leadline marked in feet. The true length by the standard is entered in the column headed "D" and the corresponding length of leadline under the column headed "M." The corrections to leadline soundings are obtained by subtracting the leadline

values from the standard. If the error of a leadline is more than 0.5 foot, it should be remarked.

3–68 Sounding leads.—Sounding leads in standard weights of 5, 7, 9, 14, 25, 50, and 80 pounds can be requisitioned from Naval Supply Depots, and other weights can be purchased from commercial sources. Sounding leads weighing 25 pounds or more are for use with wire sounding machines. The small leads, less than 25 pounds, should have a cup-shaped depression in the bottom to receive tallow, soap, or other arming material to obtain bottom samples. Each survey unit should have one lead with a snapper-type sampling device attached (see 3–128). Various methods may be used to attach the lead to the leadline. The preferable method is to make the leadline with a galvanized thimble at the lower end to which the lead is attached by a shackle. The sounding lead and the snapper sampling lead can be interchanged on the same line; however, the latter should not be used for sounding.

3–69 Sounding with a leadline.—As stated in 3–65, the leadline is used primarily to supplement echo sounding on modern survey launches. If a leadline or sounding pole is to be used extensively for sounding in shoal water, a sounding chair should be mounted on the starboard side of the launch. When leadline soundings are taken, the lead must be heaved ahead far enough to allow it to sink to the bottom so that the leadsman can feel the bottom and observe the sounding when the leadline is taut and vertical. The speed of the launch shall be reduced, if necessary, to obtain vertical soundings.

It requires some practice for a leadsman to become proficient with the leadline and to learn to read it correctly. At least one man in a launch party should be trained in the use of the leadline.

3–70 Sounding machines.—A sounding machine is a mechanical device, operated either manually or by power, used to measure, with wire, depths of water too great for the handlead. Like the leadline, the sounding machine is seldom used for hydrography. It is used principally to obtain bottom specimens, to make vertical cast comparisons with echo soundings, or to make oceanographic observations.

There are two types of sounding machines in use by the Coast and Geodetic Survey. A small, portable machine which is hand-operated and used on launches; and an LL-type electric sounding machine used on ships and auxiliary vessels where a power-driven machine is needed. A third type of machine capable of sounding to 6,000 fathoms with piano wire is no longer used. On new survey vessels, the power sounding machines will be replaced by oceanographic winches which can be used for the occasional deep soundings required.

3–71 Hand sounding machine.—The hand sounding machine (Fig. 21) has a bronze reel which will hold more than 150 fathoms of stranded sounding wire. The brake is a wood-lined clamp operated by a small handle above the reel. The hand cranks are hinged so that they can be disengaged from the shaft while the wire runs out, and engaged for reeling in. The machine is usually mounted at the stern of the launch and the wire leads to a registering sheave overhanging the stern far enough to keep the wire clear of the propeller. The machine is used to obtain bottom samples in depths too great for the handlead, to obtain serial temperature and salinity observations on small craft, and is frequently adapted for use with the Price Current Meter.

3–72 Electric sounding machine.—The LL-type sounding machine (Fig. 22) has a reel with a mean circumference of ½ fathom and will hold 900 fathoms of stranded wire. It is driven by electric power, has a clutch and brake arrangement which permits free fall of the sounding lead, and a variable speed for reeling in the wire. It is usually mounted on or near the bridge. The wire leads over a registering sheave suspended above the machine to a fair-lead attached to a pipe cross which turns freely on a pipe boom rigged over the side of the ship. It is used most frequently for obtaining bottom

FIGURE 21.—Hand sounding machine.

samples, and may be used for oceanographic work such as vertical lowerings of a bathythermograph.

3–73 Registering sheaves.—A registering sheave (Fig. 23) consists of a grooved wheel mounted in a yoke so that it will revolve freely, and connected by gears to an indicator which registers the amount of wire payed out. Sounding sheaves measure the wire in fathoms and tenths or in meters and tenths. The depths may be registered on a counter or by pointers on a series of dials. Each sheave must be calibrated for the size of wire used in the operation. When in use, the wire must be in contact with the bottom of the groove in the sheave for one complete revolution to prevent slipping. The sheave may be calibrated most accurately by running the wire over it for an accurately measured distance along a wharf or other level space. The wire must be kept taut to prevent slipping during this operation. The calibration should be repeated as a check. Correction factors should be computed if necessary (see 5–93).

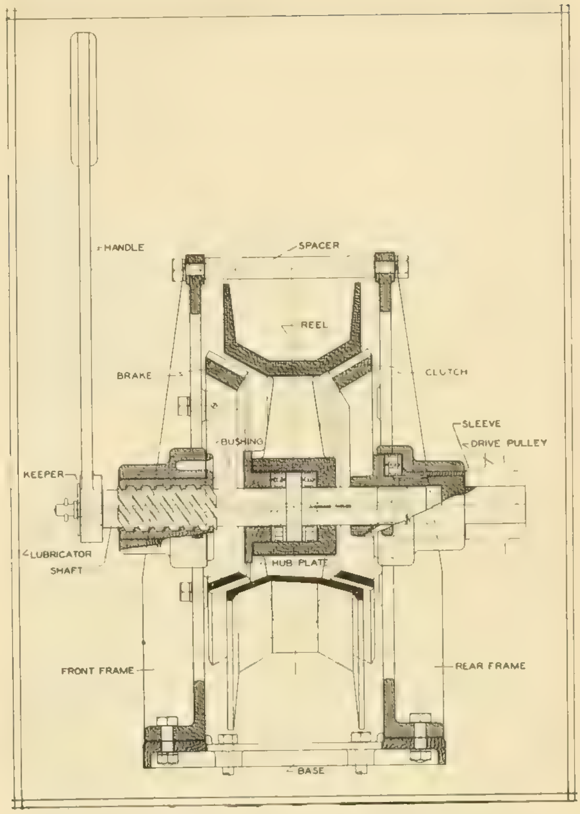


FIGURE 22.—LL Type electric sounding machine.

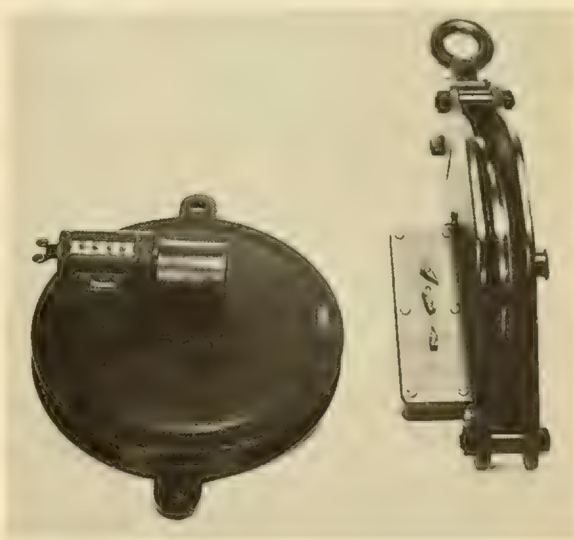


FIGURE 23.—Two types of registering sheaves.

3–74 Sounding with oceanographic winch.—When the ship is equipped with

oceanographic winches and there is not sufficient deck space to mount an LL-type sounding machine, vertical cast soundings may be obtained with an oceanographic winch. In most instances a 5/32-inch flexible steel cable will be used on the winch. A bathythermograph winch with 3/32-inch flexible aircraft cord may be used to a depth of about 400 fathoms. A registering sheave must be used in either case and the sheave must be calibrated for the size cable being used. If the sheave measures depth in meters, the sheave reading should be recorded in meters and the equivalent depth in fathoms entered below it.

3–75 **Stranded sounding wire.**—Stranded sounding wire is composed of seven tightly twisted strands of double-galvanized No. 24 B.W.G. gage wire, and has a breaking strength of not less than 500 pounds. It is furnished in 300-fathom lengths, packed with powdered lime in sealed cans. The diameter of the stranded sounding wire is 0.065 inch.

When it is necessary to splice stranded wire, a regular long wire splice should be made, with the wires ending at varying distances apart throughout the length of the splice. The ends should be tucked and the splice seized with fine copper wire at both ends and one or two places in the middle. The whole should be cleaned with muriatic (hydrochloric) acid and washed with a thin coating of solder.

The reel of the sounding machine should be dry and freely coated with mineral grease before the wire is wound on it. New wire should be coated with oil as it is put on the reel. When in use, and especially after the last sounding of the day, the wire should be run through a piece of well-greased canvas as it is reeled in. A brush dipped in heavy oil should be held occasionally against the wire on the reel while reeling in, and the reel of wire should be well wrapped with oil-soaked cloths. The sounding machine should be protected by a canvas cover when not in use.

3–76 **Echo sounders.**—Nearly all soundings are obtained by echo sounders which record a continuous profile of the bottom under the survey vessel. Various instruments have been used in the past. Three types of recording sounders now in use for survey purposes are described in the following paragraphs and no others shall be used unless specifically authorized by the Director.

All echo sounders operate on the basic principle that a sound produced near the surface of the water will travel to the bottom and will be reflected to the surface as an echo. The echo-sounding equipment is designed to produce the sound, receive and amplify the echo, measure the intervening time interval, convert the interval into units of depth measurement, and record the depths on a moving graph. The sound is an electric pulse which is mechanically converted to sound by a transducer in the hull. Transducers with various frequencies are used for different ranges of depth and for specific purposes. A low frequency is used for sounding in deep water, since high frequency signals are subject to greater absorption and require greater initial power for successful use in deep water (see 3–96 to 102).

Sound travels in water at a fairly constant velocity; however, this velocity changes with temperature, salinity, and depth (pressure). Echo-sounding instruments are operated for a certain assumed velocity of sound, known as the calibration velocity, and any sounding is in error by an amount directly proportional to the variation of the actual from the assumed velocity.

Velocity corrections shall be determined on all hydrographic survey projects, but corrections may be disregarded when they are less than half of one percent of the depth.

3–77 **EDO 185 (AN/UQN).**—An echo sounder known as EDO 185, or AN/UQN (Fig. 24), is standard equipment for hydrographic surveys in depths greater than 100 fathoms. The transmitter, oscillator, receiver, power supply sections, recorder, indicator, and control panel are contained in a cast aluminum alloy cabinet designed for bulkhead mounting. The EDO 185 is not a portable sounder, although it is possible to mount it in a launch for special surveys.

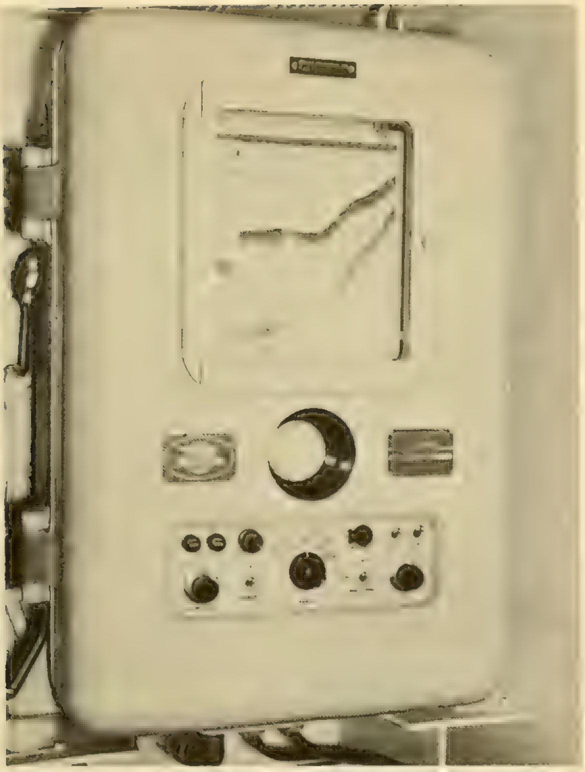


FIGURE 24.—Installation of EDO 185 (AN/UQN) echo sounder.

Complete instructions for operation and servicing the equipment are contained in a manual furnished by the manufacturer.

A single phase power source of the 500 watts at 110 volts, 60 cycles is required to operate the EDO–185. The sounder draws only 330 watts when operating, but additional power is required to start the motors. The instrument is calibrated for a sound velocity of 800 fathoms per second at 60 cycles. A constant frequency must be maintained to provide accurate soundings. The drift from 60 cycles should not exceed 0.2 cycle at any time.

In order that a constant frequency power source may be assured, the Coast and Geodetic Survey provides for each installation of the EDO–185 a 60-cycle frequency standard which drives a power amplifier of sufficient size to operate the scanning motor. On early models it was necessary to make some changes in the wiring to use the constant frequency power source, but later models provide connecting posts and a two-position switch for easy adaptation. The motor is started on the uncontrolled ship's power and is switched to the controlled power for operation. *Failure to follow this procedure in starting the recorder can result in damage to the equipment.*

3–78 **Operating characteristics.**—The EDO 185 records soundings on Type L Teledeltos paper which has a scale width of approximately 8¼ inches. The paper is supplied in 100-foot rolls. The equipment was designed to provide a paper speed of one inch per minute on the 600-foot scale; 10 inches per hour on the 600-fathom scale, and 1 inch per hour on the 6,000-fathom scale. As used on Coast and Geodetic Survey ships, the gears have been changed to double this paper speed.

The accuracy of recorded soundings is a function of the constant frequency (3–77) and the speed of the stylus. At the calibrated speed of sound, 800 fathoms per second, the stylus should travel from the zero line to the 600-fathom line in 1.5 seconds on the fast speed, or from the zero to 6,000 fathoms in 15 seconds. The stylus speed should be checked at the beginning of the season and once or twice during the season. This speed is a function of the diameter and speed of the drive pulley and should always be checked if a new pulley is installed.

The stylus belt speed can be measured by the following method: Release the fathogram paper drive so that the paper will remain stationary. Cut two small slits in the paper, one at the zero line and the other at the bottom line of the graph. Apply a small voltage to the chart plate and stylus needle in such a manner that electrical contact will be made as the needle crosses each slit. The system should be hooked to a chronograph and the period between contacts measured against time as marked from a mean time break-circuit chronometer. The speed of travel can be measured on either the 600- or 6,000-fathom scale.

If desired, the recording mechanism can be turned off and the depth viewed on a 3-inch cathode-ray tube. The timing circuits

for the tube are not connected to the stylus motor and are independent of the frequency of the power source. The circuits are factory adjusted for a nominal calibration velocity of 800 fathoms per second. In time these circuits may drift and there will be a difference between recorded soundings and the depth shown in the scope. This feature shall not be used for hydrography.

The sounder is used with a transducer designated AT–200A–UQN–1 designed to operate at a frequency of 12 kc (see 3–105).

3–79 Use of multiple stylii.—When sounding on the 6,000-fathom scale, soundings cannot be scaled from the fathogram with an accuracy much better than 10 fathoms. In order to extend the use of the 600-fathom scale, stylus belts with one or two additional stylus holders can be used. The holders are spaced on the belt at a distance equal to that between the top and bottom marks on the fathogram paper, that is, when the first stylus is at the 600-fathom mark the second stylus is at the zero mark. The extra holders do not contain keying contacts. When more than one stylus is used, it is necessary to install a thin plastic guard just above the zero mark and just below the 600-fathom mark to prevent simultaneous markings by two stylii. Since the keying stylus always marks the initial pulse it is sometimes difficult to scale the soundings recorded over the initial marks in the 600- to 700- and 1,200- to 1,300-fathom range. This is particularly true when the bottom has a very gradual slope. Doubling the paper speed (3–78) usually solves this problem. If difficulty is experienced in reading the soundings at the doubled paper speed, a cutout switch may be installed and the initial trace eliminated by manual operation of the switch.

3–80 Operation of EDO–185.—Maintenance of the EDO–185 is the responsibility of qualified technicians aboard ship; however, unskilled personnel can be trained as operators in a short time. It is advisable to have a technician start the sounder and check it for satisfactory operation one-half hour before beginning the day's work. The operator should be trained to observe and report indications of malfunctioning of the recorder. The initial pulse should always be recorded at the zero line, or an adopted initial corresponding to the depth of the transducer. Any variation of the initial should be reported and the initial adjusted in order to avoid tedious application of corrections. The gain should be maintained at the highest point possible without causing spurious marks on the graph. If the record becomes faint when good signals are received, it may be caused by a coating on the platten. A frequency meter is included in some installations. The meter should always read 60 cycles and variations in excess of 0.2 cycle should be recorded and reported immediately.

All servicing, adjustment, or repair shall be made by qualified technicians. Operation of this equipment involves the use of high voltages. Operating personnel must observe safety rules at all times.

To ensure proper operation of the EDO–185, a complete check of the S–201 keying assembly shall be made before starting a hydrographic survey. Dirty contacts in this assembly may cause errors of several fathoms in the recorded soundings. A normal initial mark on the fathogram does not necessarily provide assurance that the keying assembly is functioning properly. To detect malfunctioning, listen carefully to the outgoing pulse with the headphones and the instrument operating on the 600-fathom scale. The sound should be a clear, sharp "beep." Check across the output to the transducer with an oscilloscope. A uniform rectangular pulse lasting about 15 milliseconds should be produced. A daily check should be made with the headphones, and a weekly check with the oscilloscope.

If the S–201 keying assembly does not function properly, it should be disassembled and the contacts thoroughly cleaned. Adjustment after assembly is sometimes difficult and time consuming and shall be accomplished by a competent technician.

3–81 Precision Depth Recorder (PDR).—The Precision Depth Recorder (usually shortened to (PDR) was developed jointly by

Lamont Geological Observatory of Columbia University, the Times Facsimile Corporation of New York, and the Western Electric Co. under sponsorship of the U..S. Navy. Development was prompted by the need for precision depth recordings in the ocean deeps on an expanded scale. It is used by the Coast and Geodetic Survey on major ships in depths where soundings cannot be recorded on the expanded scale of the EDO–185. The PDR equipment is not designed to be portable.

A typical installation (Fig. 25) consists of the Mark V recorder wired to utilize the transmitter, receiver, and transducer of the AN/UQN (Navy designation) series of depth recorders manufactured by the EDO corporation of College Point, New York. A service manual and instructions for installation are furnished with each equipment.

The combination of the PDR with AN/UQN depth recorder gives a sonic sounding system which will provide nearly continuous records of the ocean depths. The PDR equipment is used to supplant the recorder unit of the sonar sounding equipment and provides a sounding record with a scale expansion and an accuracy beyond the capability of conventional sonar sounding equipment.

The scale of the MK V recorder is 18.85 inches equals 400 fathoms or about 1 millimeter equals 1 fathom. The estimated instrument accuracy is at least one part in 3000 exclusive of vagaries of propagation and bottom reflection of sound in sea water. The equipment will operate in any depth of water, being limited only by the power capabilities and signal/noise ratio of the sonar sounding set installation.

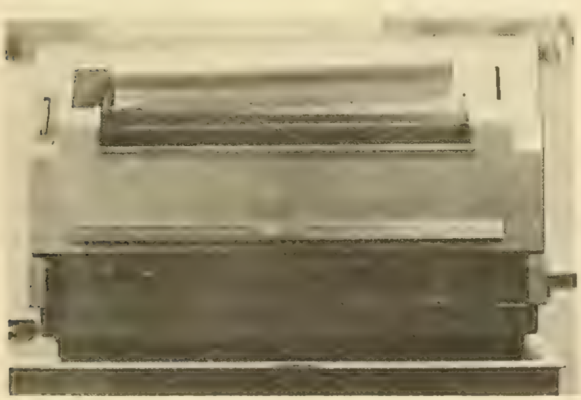


FIGURE 25.—Precision Depth Recorder.

To provide precision display of the results from the sonar sounding equipment, the PDR has some important features not found in conventional equipment. A high precision tuning fork controls the slip free drive of the Facsimile-type Recorder. Under ordinary operating conditions this provides a timing function better than one part in 1,000,000. The velocity of 800 fathoms/second is used for conversion of time measurements to depth.

A second feature is programmed gating. When operating conditions are most favorable the PDR will trigger the sonar equipment and record the results at the rate of 60 operations (pings) per minute. This mode of operation is known as HDR (High Density Recording). HDR usually works well in relatively shallow depths up to 1,500 fathoms where the return echoes are strong. However, at greater depths where the echoes are weaker, difficulty may be experienced with HDR because the outgoing ping and reverberation may use up the portion of the recording paper where the return echo would be recorded. In another case it may be found that the deep sea scattering layer tends to obscure the record of the bottom echoes. Also noisy sea conditions, poor bottom reflectivity, and possibly a detuned sonar receiver tend to give a low signal/noise ratio which makes it difficult to identify soundings. For such operating conditions the PDR provides programmed gating which permits the transmitter and recorder to operate in a preset sequence arranged to minimize the noise on the record and at the same time give a maximum density of sampling.

A third feature of the PDR is that depth and time intervals are written on the graphic record simultaneously with the soundings. The four-hundred fathoms of record is divided into twenty-fathom intervals and these so-called twenty-fathom markers are broken by time intervals. On Navy equipment the time interval is usually three minutes while the Coast and Geodetic Survey pre-

fers a five-minute time interval. This time interval is controlled by a fixed cam set at the factory. The precision of the time intervals is very high as the cam is controlled by the same synchronous motor used to drive the scanning mechanism. One roll of paper will last about a week on 24-hour operation.

3–82 Checking accuracy of PDR timing circuits and mechanism.—The most common check made on the operation of PDR equipment is to record time ticks from WWV directly on the graphic record. To make this check the WWV signal from radio is fed directly into the PDR headphone jack and a record made for a period of several minutes. This can be done without much interference with the soundings and it is common practice to make such a recording once each four-hours watch. If the speed of the stylus is correct (400 fathoms per second) the WWV ticks will fall one under the other and the leading edge of the ticks will be nearly parallel to the twenty-fathom markers. By making recordings several hours apart, it can be determined whether the PDR is running fast or slow and the precision of the timing function ascertained. If the WWV ticks appear to move to the left about 8 fathoms over a period of four hours continuous operation then the PDR is running a little fast and the error is one part in 720,000. Should the movement be to the right the PDR would be running slow. A word of caution: The adjustment of the precision fork which controls this accuracy is not a normal field adjustment and should not be attempted unless proper equipment is on hand to insure accurate results.

The main reason for making this check is to be sure the synchronous drive system is operating at synchronous speed. Faulty soundings will result if the scanning mechanism is operated at other than 400 fathoms per second.

3–83 Identification of 400-fathom phasing.—The PDR graphic record is continuous and the changes in phase are automatic. Thus the value of the baseline must be known at all times as it can be any multiple of 400 fathoms. The value of the baseline is denoted by such an expression as 0 plus, 400 plus, 800 plus, 1,200 plus, etc. At every change of phase the value for the baseline should be entered on the graphic record. When the phase remains constant, the value of the baseline should be recorded at intervals of 30 minutes.

Methods for determining the absolute value of the baseline vary depending on the equipment available. The most common method is to switch back to the EDO-185 and record a few soundings on the 6,000-fathom scale. Most installations permit this to be done. Where it is feasible, a second EDO-185 can be turned on for brief intervals or another sonar sounding set operating at a different frequency can be used to give this information. When conditions are favorable, it is possible to check the phase by listening on a pair of headphones and counting the number of seconds between the transmission and reception of the last ping of a group. The slow drum recorder equipment mentioned in the PDR instruction book is not available.

3–84 EDO–255 Depth Recorder.—The EDO–255 Depth Recorder, Model C (Fig. 26) was developed jointly by the EDO Corporation and the Electronics Laboratory of the Coast and Geodetic Survey to comply with requirements and specifications agreed on by various agencies interested in the project.

The instrument is a portable, supersonic, graphic recording, echo sounder, designed for accurate hydrographic surveys in shallow to moderately deep water by vessels of any size.

Its range is from about 2½ feet below the transducer to 230 fathoms. All electrical components except the transducer, are housed in a compact, sturdy, weather-proof cast-aluminum cabinet. The recorder will operate in any position.

The principal characteristics of the EDO–255 are:

(a) It is designed to operate from a 110–115 volt, single phase power source with a frequency range of about 57.5 to 62.5 cycles.

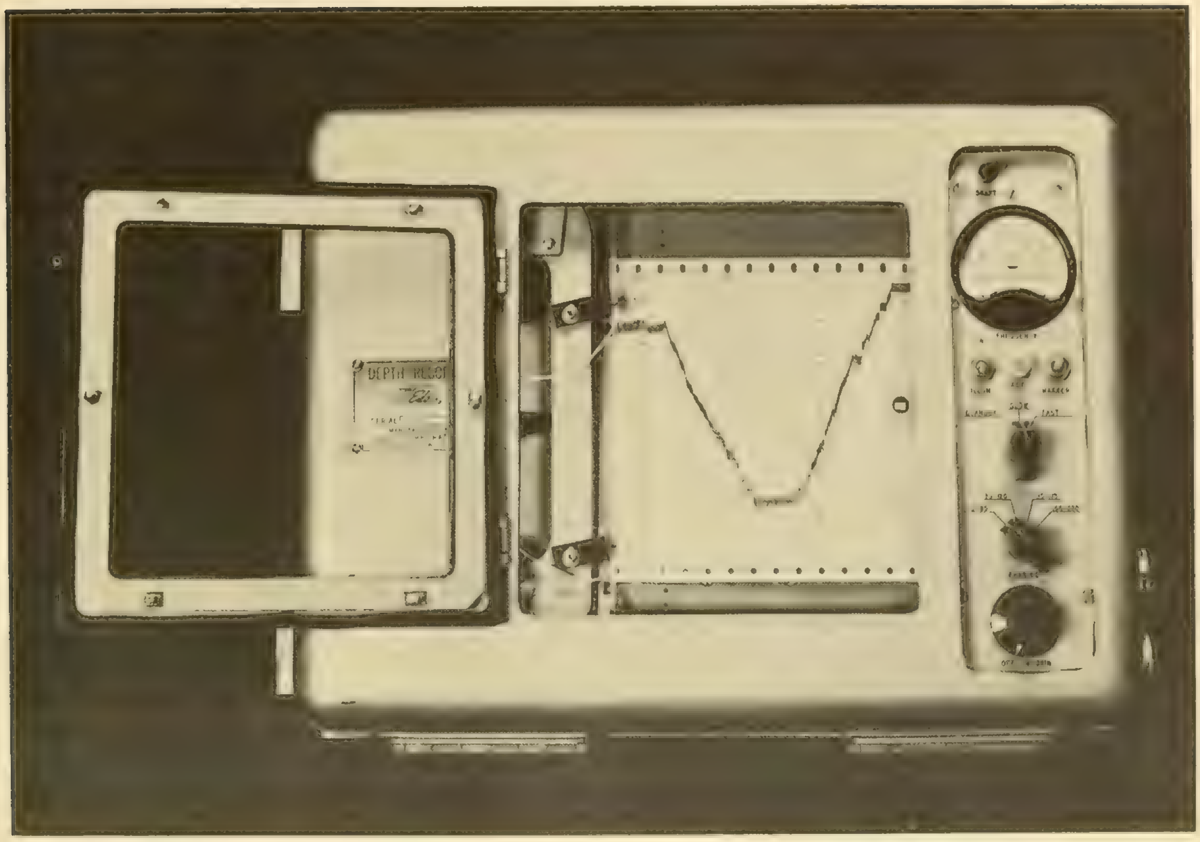


FIGURE 26.—EDO 255–C, shoal water echo sounder.

For portable installations a rotary converter or inverter with variable frequency control may be used with power derived from a well-regulated 12-volt D.C. source or a 12-volt battery.

(b) A synchronous stylus drive motor assures correct stylus speed when the motor is powered by a supply source of dependable frequency. A frequency meter graduated to 1/10 cycle is mounted on the control panel where it can be constantly monitored and the converter adjusted to maintain the desired frequency.

(c) The depth recording is linear. This facilitates reading the fathogram and substantially reduces stylus and paper adjustment errors.

(d) The instrument will record depths from 2½ to 230 feet, or about 1 to 230 fathoms in four phases of 65 units each and having an overlap of 10 units. The phase shift is accomplished by a switch on the control panel. Phase comparisons and adjustments can be made on the bench. The adjustment for each phase is made by shifting the phase contacts slightly to reduce the phase error to zero (see 3–86).

(e) The instrument is capable of recording in units of feet or fathoms, however, the operator cannot shift from one mode to the other at will. The stylus motor is connected directly to the drive pulley. In order to change from feet to fathoms, or vice versa, it is necessary to reposition the motor, an operation requiring about 30 to 45 minutes (see 3–87).

(f) The position of the initial mark on the fathogram is adjusted by the draft control knob on the control panel. The initial should not be set until the recorder has been in operation at least 15 minutes. The initial is recorded on the first phase only.

(g) Soundings are recorded on an electrosensitive paper, without a carbon core or aluminized backing, made by the Timefax Corporation. The surface is a lighter grey than the Teledeltos paper, it does not smudge as easily, and is dust free. There are four printed scales: 0 to 65, 55 to 120, 110 to 175, and 165 to 230.

(h) Recording is accomplished by a stylus mounted on an endless rubber belt. As the recording stylus travels across the paper, it makes contact with a trolley rail which serves to transfer the signal from the receiver to the stylus and also acts as a guide to assure straight line recording. A keying brush extending upward is also attached to the belt and is guided by a groove in the plate above it. This brush makes contact at one of four adjustable keying contacts as selected by the phase switch. It should be noted that the keying brush and the stylus are similar in construction and method of attachment to the belt. The keying brush does not key the EDO–255 transmitter directly. This function is accomplished by a multivibrator circuit which is triggered by the keying brush on the belt.

(i) The paper is drawn across the platen at a rate of one or two inches per minute by one of two paper drive motors. The selection of paper speed is made by means of a switch on the control panel.

(j) One barium titanate transducer (see 3–104) operating at a frequency of 37.5 kc is used to produce the sound wave and receive the echo. The transducer furnished is equipped with an impedance matched cable which is part of the electrical circuit. *This cable must not be cut.*

3–85 Calibrated velocity and variable frequency.—The EDO–255 is designed so that the frequency of the power supply can be varied to accommodate changes in the velocity of sound in sea water through a range of about 4,600 to 5,000 feet (767 to 833 fathoms) per second. It is possible to vary the frequency over a range of 57.5 to 62.5 cycles, thus decreasing or increasing the calibrated velocity of 4,800 feet per second at 60 cycles. The mean velocity of sound in the water area must be determined by velocimeter observations or by serial temperature and salinity observations and computations. The frequency can then be adopted which will compensate for a variation from the standard 4,800 feet at 60 cycles, thus avoiding the necessity of applying velocity corrections to recorded soundings (see 5–120). A change of 0.1 cycle will change the calibrated velocity 8.0 feet, thus if the velocity of sound in sea water is determined to be 4,830 feet per second, the frequency should be set and maintained at 60.4 cycles. The echo sounder operator must continually monitor the frequency and make any adjustment necessary to hold it as nearly constant as possible (see 5–55). It should be remembered that a variation of 0.3 cycle represents a change of 0.5 percent in the soundings.

3–86 EDO–255 phase adjustment.—Each successive scale or phase must be properly correlated with the next shoaler one, that is, a bottom echo at 60 feet on the first phase should appear at 60 feet on the second phase, etc. If the soundings do not agree, the keying contact must be adjusted to bring the two into agreement. This test and adjustment can be made only in the feet mode. To make the adjustment, set the fathoms calibration switch to the ON position, the phasing switch to 0–65, and function switch to slow. Turn the draft adjustment so that the zero depth mark (initial) is moved down to read 55 feet. Switch to the B scale (55–120) and the mark should appear at 55 feet. If not, the number 2 contact must be adjusted until the stylus mark appears at 55 feet. Switch back to the A scale (0–65) and the mark should again appear at 55 feet. The C and D scales can be similarly correlated. These adjustments should be made by a qualified technician.

Since the initial appears only on the first phase, the operator should check the initial setting periodically when the recorder is being operated continuously on other phases. This check can best be done when the vessel is turning about between lines.

3–87 Feet or fathom mode.—The EDO–

255 cannot be switched from feet to fathoms operation as has been the custom with the 808 fathometer. When it becomes necessary to change modes, the stylus drive motor must be repositioned and the fathoms calibration switch placed in the ON position. The change shall be made by a qualified technician, and unskilled personnel are not authorized to attempt it. The hydrographer should plan his work so that changes, if required, shall be kept to a minimum.

3–88 **Operating manual.**—A technical manual is furnished with each EDO–255 recorder and contains complete instructions for servicing and adjusting the instrument. Personnel assigned to operate the recorders should be instructed in procedures for changing paper rolls and stylus needles as well as normal operating procedures. All other servicing or repair shall be done by electronic technicians. A record of servicing and repairs should be kept for each instrument, and should accompany it if transferred to another survey vessel or party.

3–89 808 **Fathometer.**—The 808 Fathometer (Fig. 27) is a semiportable, supersonic, graphic-recording, echo-sounding instrument designed for hydrographic surveying in shallow to moderately deep water from vessels of all sizes. Its range is from about 2 feet below the transducer to 160 fathoms. The 808 Fathometer has been the standard shoal water sounder since 1939. The sounder records on a graph through a stylus operating in a circular sweep. The range of scale of the record paper is 55 divisions, and by means of a phasing arrangement with a 20-unit overlap, three other ranges may be recorded thus providing for an expanded scale covering a range of 0 to 160 units, either feet or fathoms.

A contract has been awarded to reengineer the 808 Fathometer to incorporate several new features which will improve its capabilities and correct some of the operating deficiencies of the old models. The specifications are not fixed, and a detailed description is not available.

3–90 **Operating characteristics of 808 Fathometer.**—The fathogram paper used on 808 depth recorders is designed for the following conditions of operation:

Calibrated for velocity of sound.	820 fm/sec . .	800 fm/sec.
Center reed of tachometer.	67.1 cps . . .	65.5 cps.
Motor armature speed	4,026 rpm . .	3,928 rpm.
Stylus arm speed, feet	671 rpm . . .	654.6 rpm.
Stylus arm speed, fathoms.	111.833 rpm .	109.104 rpm.
Time per revolution, fathom scale.	0.5365 sec . .	0.5232 sec.
Effective length of the stylus arm (4.419 inches).	11.224 cm . .	11.224 cm.
Chart paper speed, foot scale.	2 in/min . . .	1.95 in/min.
Chart paper required .	15, 15UE or ES–9.	TCI–3008.

3–91 **Motor speed.**—The accuracy of the recorded depth is directly related to the motor speed, and the motor must always rotate at calibration speed. The motor speed is controlled by means of a centrifugal type governor attached to one end of the motor frame. A Frahm vibrating-reed type of tachometer provides a visual monitor of the motor speed. The tachometer is composed of seven reeds; the middle reed, vibrating at maximum amplitude, indicates correct motor speed for the calibrated velocity of sound in seawater. Tachometers may be constructed for any desired velocity, but only two are used: 800 or 820 fathoms per second. The fathometer operator must be constantly alert and adjust the motor speed when necessary to keep the middle reed vibrating at maximum amplitude (see 5–55). The fact that the motor speed is correct should be recorded at frequent intervals. Variations in motor speed are indicated by the tachometer and the paper speed, but the paper speed is not always a true measure of the motor speed and care shall be taken that paper slippage is not misinterpreted as incorrect motor speed. Daily checks should be made on paper and speed and rpm count against a stop watch, and recorded (see 5–110 and 111).

3–92 **Stylus arm length.**—Accuracy of recorded depth also depends on the rate of travel of the stylus over the fathogram, and the radial distance to the stylus contact must be 11.224 cm (4.419 inches). An abnormal

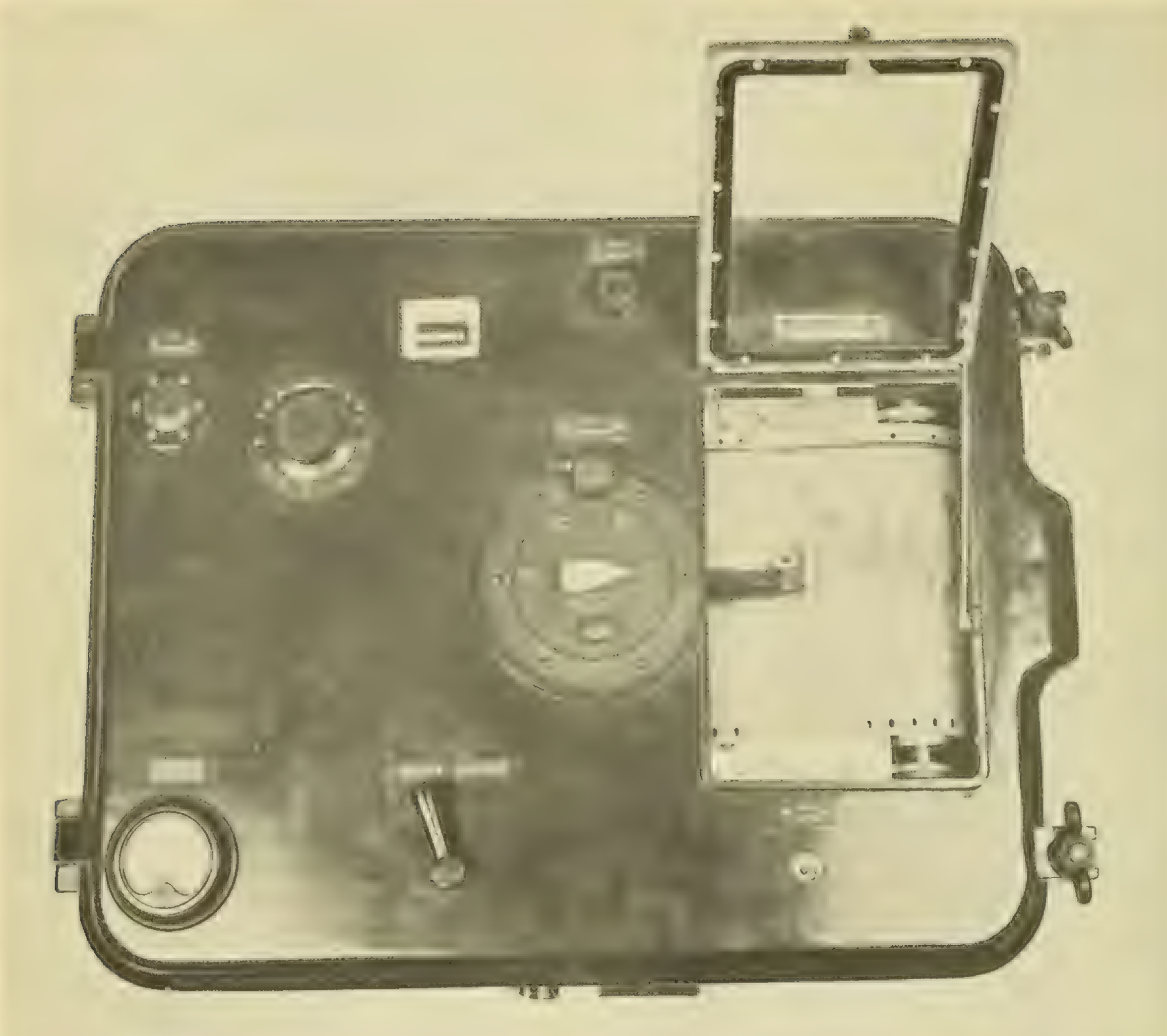


FIGURE 27.—808 type shoal water echo sounder.

length of stylus arm is indicated when the stylus and printed arcs do not coincide, the center of rotation being correct. The length can be checked by comparing the stylus arc with arcs of various radii drawn on a plastic sheet. The effective length should be correct within 0.040 cm (0.010 inch). The effective length varies with projections of the spring stylus. Adjustment is provided in the stylus holder trunion screws. The screws should be locked, or sealed, to prevent movement, by the lock screws in the back of the metal frame holding the stylus. If the screw adjustment is insufficient, the bakelite insulator can be shimmed or filed.

3–93 Alignment of fathometer paper.—Since the 808 echo sounder is designed to record soundings with a circular sweep, the fathogram paper must be correctly positioned with respect to the radius of rotation of the stylus arm. The paper alignment is correct when the paper is moving across the platen so that the extended centerline of the paper will pass through the center of rotation of the stylus arm and the paper moves in a direction parallel with the lines on the paper. The operator should occasionally check the paper alignment by causing a fix mark to follow one of the printed arcs on the chart. If the fix mark follows the arc

the needle length and paper alignment are correct. If the fix mark agrees with the printed arc at one end only, the paper alignment is incorrect and should be adjusted. If the fix mark agrees at both ends of the printed arc but is out in the center, the needle length should be corrected. A continuous variation of the initial is an indication that the chart paper may not be running true. This is usually caused by uneven winding of the chart on the take-up reel, and can be corrected only by starting over with another reel (see 5–111).

3–94 Phasing differences.—The 808 recorder is designed to record depths to 160 feet or fathoms in four overlapping phases designated A, B, C, and D. The initial is recorded only on the A phase. The instrument is made to record on the proper scale or phase by means of a phasing head which is rotated to the proper position and locked in place by a spring operated pin. Phasing errors may be caused by small errors in construction of the instrument, by natural wear on the pin and holes in the plate, or by wearing down the stylus needle while operating on a scale other than A. The fathometer operator should be trained to make phase changes in a clockwise direction, and to be certain that the locking pin is firmly in place (see 5–112). During hydrographic survey operations the phasing head should be shifted and locked in exactly the same manner used in calibration by bar check or phase comparison. When sounding on any of the 3 deep phases, the recorder should be shifted back to the A scale occasionally to check the initial setting and adjust it if necessary.

3–95 Voltage and gain.—The recorder operates from a 12-volt storage battery. Voltage may be allowed to vary to a limited extent; however, significant errors will result when voltage drops too low. The operator should notify the hydrographer if the voltage falls below eleven volts. The gain should always be set as high as possible without producing spurious traces on the fathogram. The gain should be the same for survey operations as for bar-check or comparative sounding calibrations (see 5–110). In areas of heavy kelp or grass where the bottom trace may be lost, the gain may be temporarily adjusted, but should be reset when the area is cleared.

3–96 Echo sounder transducers.—As its name implies, an echo sounder measures the time required for a sound wave to travel from its point of origin to the bottom and return, and converts time to distance or depth. Various instruments and methods have been devised to produce the sound and receive its echo. The transmission of sound used in echo sounding is dependent on certain properties of the water and on the reflecting surface. Ideally the water should possess constant physical characteristics throughout the entire depth, thus resulting in constant velocity of sound from surface to bottom; there should be no attenuation of sound; and there should be 100 percent reflection from a bottom parallel to the surface. These ideal conditions never exist.

That part of the echo sounder which converts electrical energy to sound energy is called a transducer. The same part, or one like it, is used to convert the echo to electrical energy to be amplified and recorded as a measured depth. An echo sounder transducer is usually designed to operate at a specific frequency. When echo sounding equipment is classified according to the frequency of the transmitted sound, it is said to be either sonic or supersonic. Devices that utilize acoustic waves of a frequency that are audible to the human ear are generally classified as sonic instruments, and when higher frequencies are used they are called supersonic or ultrasonic instruments. In practical application equipments using frequencies of 20 kilocycles or less are called sonic. The frequencies most commonly used for echo sounding can also be divided into three groups: low frequencies, or those below 15 kilocycles; medium frequencies, or those between 15 and 50 kilocycles; and high frequencies, or those above 50 kilocycles. At its designed or resonant frequency the transducer is most efficient in producing sound

energy and is most sensitive to its reception. Transducers have been designed for a wide range of frequencies from near subaudible, below 50 cycles per second, to supersonic frequencies of 200 kilocycles or more. Each range of frequencies has distinct advantages for use in a certain depth range.

3–97 Sonic frequencies.—Sonic frequencies can be generated in the water at a high-energy level. Most echo sounders used in navigation employ sonic frequencies. Because of the low absorption at sonic frequency their high penetrating power makes them useful for deep soundings. Sonic frequencies have certain restrictive limitations. These frequencies cannot be used to measure extremely shoal depths with a high degree of accuracy. Most of the energy of water and ship noises is in the sonic-frequency range and, therefore, sonic soundings are more susceptible to interference from strays of this kind. Because of their long wave lengths, these low frequencies cannot be directed, or beamed, to an advantageous degree without using transmitting and receiving units of a prohibitive size.

3–98 Supersonic frequencies.—Supersonic frequencies overcome, to a large extent, most of the disadvantages of sonic frequencies. The advantages of supersonic frequencies are: high directivity with small transmitting and receiving units and resulting concentration of sound energy; less interference from ship and water noises; shoal depths can be measured; a more detailed profile of irregular bottom can be obtained; and side echoes are reduced. On the other hand, there is greater attenuation of sound, and strays may be recorded when sounding in turbulent water, or in areas where there are sharply defined changes in water temperature or density at various depths. With present designs of transducers it is not possible to sound in very deep water when using high frequencies.

3–99 Acoustic elements.—There are two principal parts of a transducer: the acoustic element and the mechanical support of the element which may or may not function as part of the acoustic system. There are numerous types of acoustic element materials which are constructed in a variety of shapes and sizes. Only the materials and designs used by the Coast and Geodetic Survey will be described in detail.

In general, the acoustic elements may be grouped in two classes, magnetic and electrostatic. Of the magnetic class, the magnetostriction type is used most in echo sounding. When certain metals, such as iron or nickel, are placed in a magnetic field they will change dimension. If the metal is in the field of a coil which is energized by an alternating electric current, the metal will alternately expand or contract along the axis of the coil and in unison with the exciting current. When the alternating field corresponds in frequency with that of the mechanical resonance of the metal, maximum vibration occurs. The transducer is usually mounted so that a vibrating face is exposed to the sea water and facing the sea bottom. This face acts as a piston which, through its vibration, generates sound waves in the water. Conversely, when sound waves strike the exposed face it is set into vibration which changes the magnetic flux to produce a current in the coil surrounding the metal.

There are a number of different materials used in electrostatic transducers. Those used most are Barium Titanate, Quartz, Ammonium Dihydrogen Phosphate (ADP) and Rochelle Salts. The material is placed in an electric field rather than a magnetic field, but the effects are the same. It is normal to have opposite faces of the material coated with a thin metallic foil and the transmitter or oscillator is connected to these faces. The material changes its dimensions in unison with the applied signal from the signal generator. Some of the materials used in electrostatic transducers are cut from natural crystals, and they must be cut carefully with regard to the axis. Some of the new plastic materials now in use, such as Barium Titanate, can be molded which adds enormously to transducer design possibilities. For this and other reasons, Barium Titanate is being

used extensively to generate and detect underwater sound.

There are two principal methods of exciting a transducer to provide a sound producing power. They are shock excitations and excitation from a pulsed transmitter. A transducer may be shock excited by discharging into it electrical energy stored in a capaciter or condenser. The transducer rings and sends out a train of decaying acoustic waves into the water. There are two principal advantages to shock excitation, and, when two transducers are used it is possible to obtain soundings in very shoal water.

A pulsed transmitter will excite a transducer by producing oscillation at the designed frequency for a specific period of time. The advantages of this type of excitation are that there is control of the length of the transmitted sound pulse and more power can be delivered to the transducer.

3–100 Transducer beam width.—The transducer is placed in the bottom of the vessel with the radiating face toward the sea bottom. The sound energy is directed toward the bottom in the form of a beam which may have a width varying from two degrees to more than fifty degrees. The beam may be symmetrical about its main axis or it may be wider in one direction than another. The beam width has an inverse relationship to the area of the transducer face or diaphragm. At a fixed frequency of operation the beam becomes narrower, or sharper, as the size of the transducer face increases; or for a fixed transducer size, the beam sharpens as the frequency is increased.

The width of the transducer beam has an important effect on the accuracy and appearance of the recorded echo. When the same power is used, the energy directed towards the bottom will increase as the width of beam is decreased, and, at the same frequency, the energy in the echo will be increased. The smaller beam also reduces the adverse effects of noises arriving from directions other than from the direction of the bottom. In order to obtain the greatest accuracy in echo sounding the beam should be extremely narrow. Then the echo comes from a very small area on the bottom and side echoes from slopes and other irregularities are reduced to a minimum. However, there are certain practical aspects of the operation which govern the selection of beam width to be used.

For example, it is necessary to use low frequency sound waves in deep water, but it is not practical to install in the hull a transducer large enough to produce a narrow beam at low frequencies because of the limited space between the frames of a ship which, on Coast and Geodetic Survey ships, varies from about 20 inches to 27 inches. A special narrow beam transducer with an intermediate frequency is being used experimentally for deep sea sounding. The transducer is mounted in a blister on the outside of the hull and at the end of a shaft extended through a universal joint in the hull. The unit is stabilized in a vertical position by a hydraulic system so that the beam is always directed toward the bottom regardless of the ship's motion. More accurate delineation of bottom slopes is possible through partial elimination of hyperbolic curves recorded on the fathogram by side echoes when the wide beam transducer is used.

Unless a stabilizing system is used narrow beaming can be troublesome when sounding in deep water and rough seas. As the vessel rolls the sound is beamed in a slanted line, and while the echo may not be lost, it will not be a true depth.

3–101 Attenuation of acoustic signals.—After the sound wave leaves the transducer it is continually subjected to losses in strength and is often quite weak when the echo returns to the transducer. The sound wave spreads out or radiates as it travels to the bottom and again as it returns as an echo. This causes a gradual and continuous loss of energy. Some of the energy is absorbed in the water by conversion to heat. This is similar to friction losses in mechanical systems. Absorption losses increase as the frequency of the signals is increased. These losses are important when considering the design of echo sounders intended to operate at a high frequency, but for practical pur-

poses may be disregarded for low frequencies. Scattering losses occur when the sound waves are diverted from their original direction of travel. This may be caused by a discontinuity in the water such as turbulence, aeration, changes in water density, or by solid matter in suspension in the water.

When the sound wave reaches the bottom, several things happen to it. Part of the sound is reflected as an echo and returned to the transducer. If the bottom is very rough or if the sound wave strikes it at an angle, some of the wave will be reflected away from the transducer and be lost. Part of the sound enters the bottom and may be absorbed or reflected from deeper layers of the bottom material.

3–102 **Frequency versus depth.**—Deep water echo sounders almost universally use low frequencies or those less than 15 kilocycles. Absorption losses are least at these frequencies. The beams are wide, often as much as 50 degrees (25 degrees each side of center). Such wide beams are detrimental to the accuracy of soundings in areas of steep slopes and irregular bottom. Side echoes from slopes may cover the echoes from the bottom of a valley or trench. Higher frequencies with resultant narrow beams are desirable, but because of the high rate of attenuation of such signals they are not usable in great depths. Power supplied to the transducer cannot be increased without limit to overcome attenuation as there is a limit to the driving power of a transducer. When this limit is exceeded cavitation takes place and decreases the power of the generated sound.

Medium frequencies 15 to 50 kilocycles, are used in most of the medium depth echo sounders which are generally designed to operate in depths less than 300 fathoms. In this range the transducers are quite small, the maximum dimension not exceeding 8 inches. However, the higher frequency results in a comparatively narrow beam which affords more accurate definition of the bottom.

High frequency echo sounders are characterized by small transducers and narrow beam widths. The short-wave length and narrow beam afford excellent detailed bottom definition, however, the high absorption losses restrict use of these sounders to maximum depths of about 300 feet. Most of the high frequency sound is reflected from the top of the sea bottom and there is very little reflection from lower formations. These equipments are often used in conjunction with dredging operations.

3–103 **The 808 transducer.**—The 808 echo sounder employs two identical transducers, one for sending and one for receiving sound waves. They are shock excited magnetostriction transducers composed of many laminations of thin nickel sheets. The wire used as the coupling coil between the mechanical and electrical parts of the unit is wound through holes in the stack. When assembled, these laminations make a rectangular block $6\frac{1}{2} \times 4 \times 3\frac{1}{2}$ inches. One of the large faces of the block radiates sound waves or receives the echoed sound. This face oscillates at approximately 20.5 kilocycles per second, when excited, or is set into oscillation at this frequency by the returning signal. When mounted for sounding this transducer has a beam which is 80 degrees athwartship and 40 degrees fore and aft. The long dimension of the transducer is in the fore and aft line, where it is less sensitive to rolling of the vessel. It has the disadvantage of picking up unwanted side echoes.

3–104 **EDO–255 transducer.**—The EDO–255 echo sounder employs a Barium Titanate acoustic unit and is excited from a pulsed transmitter which generates 37.5 kilocycles per second oscillation for about one millisecond. The acoustic units are in the form of thin walled cylinders, two coaxial in line, which radiate sound waves radially from their outer surfaces. This radial radiation is horizontal until it is reflected from the inner surface of a cone in which the acoustic units are coaxial. The sound is then directed downward towards the bottom. This entire unit is housed in a plastic housing filled with castor oil. One or two transducers can be

used with the EDO–255, but one transducer operation is most common. The transducer acts alternately as a sending and receiving unit. This transducer has a beam width of 20 degrees which is symmetrical about its principal axis. This narrow beam provides a high sound conversion efficiency and makes for more accurate sounding.

A new type transducer is being developed for the 255 echo sounder. It is also a Barium Titanate unit, but is made up of molded blocks of this material. The blocks radiate directly from one face to the sea water. This transducer is capable of producing many times as much sound energy as the one now in use.

3–105 The EDO–185 transducer.—The deep water echo sounder, Type UQN, uses a transducer which employs an array of 45-degree, Z-cut ammonium dihydrogen phosphate (ADP) crystals. The dimensions and arrangement of the crystals and a monel backing plate produce maximum energy transfer (resonance) at about 12 kilocycles. The mechanically active surfaces of the crystal array face downward when the transducer is installed. When energized, the vibratory motion of the crystals is transferred to the water through dehydrated de-aerated castor oil and an acoustically transparent window. The beam has a width of 64 degrees which is symmetrical about the principal axis. This wide beam is caused by the relatively low frequency even though the transducer has a comparatively large diameter of 10 inches.

One transducer is used to transmit and receive. The power delivered to the transducer is about 800 watts with a pulse length which varies from 2 to 150 milliseconds depending on the sounding scale being used. The efficient transducer coupled with low frequency and large excitation power make it possible to sound in the deepest water with the UQN.

3–106 High frequency transducers.—Two high frequency echo sounders are being used by the Bureau for limited and special surveys. These are the Raytheon DE 119 and the Bloodworth type ES 130. Their transducers are so similar that a single description will suffice for both. The acoustic element is a thin wafer of Barium Titanate embedded in a plastic housing. Their metal electrodes are secured to opposite faces which couple the electrical and mechanical parts of the systems. Radiation is from one surface to the bottom. These transducers are transmitter excited at 200 kilocycles per second. They have a diameter of 3 inches and a beam width of 6 to 8 degrees.

3–107 Care of transducers.—Transducers are sturdy devices which require only periodic inspection and occasional servicing. They should not be subjected to harsh physical shocks which may damage the housing or the interior elements.

Maintenance of magnetostriction type transducers consists essentially of cleaning the exposed side of the laminations. This surface should be wire-brushed to remove barnacles or other types of marine growth. In some installations the transducer is housed in a castor oil-filled sea chest. In this case the only maintenance required is to check the oil level about once every two to three months and see that the chest is always full. Only an approved oil furnished for this purpose shall be used. Other oils may damage the insulation on the wires.

Most electrostatic transducers have the active element emersed in a castor oil bath and the housing must be kept filled with an approved grade of oil. In some of the new transducers coming into use the active element (barium titinate) is placed in a square housing which is then filled with a plastic material called epoxy. The exposed surface of this type of transducer should be cleaned with a non-metallic, non-abrasive brush.

The electrical insulation leakage and resistance of the connections for all types of transducers should be examined at least once a month while the units are in service. The leakage is best checked with a 500-volt megger. The wire windings on 808 transducers will deteriorate with time or may be damaged. When the megger indicates leakage,

the wire should be replaced being careful to follow the original pattern exactly.

All connections should be examined to see that there is good contact and that they are firmly made. A further check on connections for magnetostriction transducers can be made with a low-range wheatstone bridge. The average resistance of the wiring in these units is less than 0.1 ohm. The overall resistance of the transducer and the cable leads to the recorder should be measured and recorded. This measurement should be checked periodically. An increase in the resistance is an indication that the connections should be re-examined.

The transducers mounted in the hulls of Coast and Geodetic Survey ships are usually exposed directly to the water and not painted. When a ship is hauled out, the exposed surfaces of the sonic projector units are cleaned while still damp using non-metallic, non-abrasive brushes so as not to mar the polished surfaces or rubber diaphragms. A metallic face is then swabbed with a solution of 1 part nitric acid to 5 parts of fresh water, washed with soapy water, and flushed with fresh water. If necessary, the surface is then polished with crocus cloth. Rubber faces are cleaned with mineral spirits, or fingerprint remover, and washed with fresh water. Detergents are never used to clean rubber units.

After being cleaned, the projectors are covered with a protective mask which is removed just before undocking. Metallic transducer faces are never painted. On ships operating in tropical waters or other areas where underwater fouling is rapid, rubber faces may be painted with a special anti-fouling paint procured from the Navy. The paint is described in specification MIL–P–15152A. The Navy stock number is G 8010–286–3177.

3–108 Installation of echo sounders.—Specific details of echo sounder installations are as varied as the number and kind of vessels used. There are some general considerations which apply in all cases.

(a) **Ship Installations.**—The recording part of the equipment is mounted against a bulkhead, or on a specially constructed mounting, in the bridge area. All echo sounders to be used in hydrographic surveys should be located in the same general area (Fig. 28). The space should be well ventilated and adequately lighted. The hydrographic team should be stationed so that they may communicate with each other without raising their voices above the level of normal conversation.

The transducers are mounted in the hull at a point somewhat forward of midships—preferably immediately below the center of position fixing operations. All transducer installations on ships are made in accordance with plans and specifications drawn or approved by the Vessels and Equipment Branch.

(b) **Launch Installations.**—Portable echo sounders are mounted in launches at an angle of about 30° with the horizontal and in such a manner that they are easily accessible for servicing. Because of the high noise level in most launches, the echo sounder operator, the recorder, and plotter should be positioned close to each other (Fig. 29). A well-lighted cabin is essential to reduce eye strain for all members of the party.

The basic electrical power in most hydrographic launches is a 150 ampere hour 12-volt battery. A typical system consists of two 12-volt batteries and a generator belt driven by the launch engine. On some ships the launches are not equipped with genera-

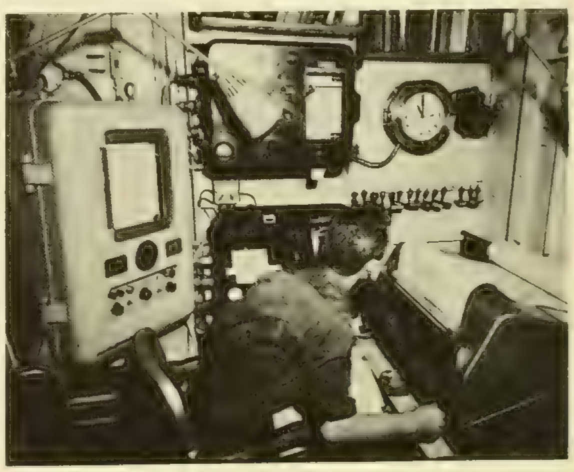


FIGURE 28.—Echo sounders installed on an ocean survey ship.

FIGURE 29.—Interior of hydrographic launch showing arrangement of equipment.

tors and batteries are charged at night aboard the vessel. Experience has shown that it is best to charge one battery while operating from the other. It is possible to operate from a battery under charge but precautions must be taken to prevent surges of excessive voltage. A 40 to 50 ampere generator is adequate and a 12-volt automobile generator equipped with a regulator will keep the batteries charged over long periods of operation. If other equipment, such as a radio, is operated from the same batteries, a larger generator may be required.

For EDO 255 installations, the 12-volt D.C. system is fed to a converter or transistor power supply which in turn provides 115 volt, 57.5 to 62.5 cycle A.C. required by the instrument. The Kato rotary converter has been used with satisfactory results but efforts are being made to replace it with a transistor power supply which is much more efficient. It is often feasible to place the Kato converter in another compartment and use an extended shaft to operate the frequency adjustment knob. A small variac in the A.C. power line to the depth recorder can be used to adjust A.C. voltage as the batteries run down. The battery leads to the converter should be as short as practicable. It is desirable to have a 0–15 volt D.C. meter across the battery being used and a 0–150 volt A.C. meter across the variac when one is used.

The transducer can be mounted through the hull or attached to the keel. A fairwater must be built around it to reduce turbulence to a minimum. The transducer is usually located nearly amidships, but no fixed rule can be given. It should not be mounted under the engine, or so far forward that disturbed water washes around it at operating speeds, and should not be aft of intake and discharge ports.

3–109 Bar check apparatus.—The bar check is a method whereby the accuracy of an echo sounding instrument may be verified. By using the bar check, the index of an echo-sounding instrument operated at a constant velocity may be adjusted to compensate for the draft of the acoustic unit and the instrumental error without knowledge of their amounts; and when accurate bar checks can be obtained through the full range of depths in the project area, compensation may be made for a velocity of sound differing from the calibration velocity of the instrument (see 5–115).

The bar may be any reflecting surface which may be lowered to a known depth below the transducer. Various types of bars have been used, such as a section of 2- to 3-inch pipe sealed at both ends, a section of sheet steel about 9 inches wide and 3 feet long, and a weighted board. One of the most satisfactory bars is one made of 6 to 8 sections of thin walled tubing, such as condenser tubes. The ends of the tubes are plugged and made water tight. The tubes are placed about ¼-inch apart and clamped in position with 3 sections of strap iron, and a hinged yoke is secured to each end of the bar. Additional weight is required to overcome the bouyancy of the trapped air and keep the suspending lines taut. The overall length of the bar should be approximately equal to the beam of the sounding launch. If the bar is to be used in depths greater

than 30 feet, it should be at least 9 inches wide.

When an 808 type echo sounder is used, one of the transducers used for sounding can be disconnected and another standard unit connected in its place. The latter unit is suspended by a marked wire and cable lead and the distance between the units will be recorded on the graph. The suspended unit must be directly below the sounding unit, or appropriate corrections applied for any offset. The sound travels only one way, from one unit to the other, and no echo is involved, therefore the recorded depth must be doubled to obtain the true depth.

The supporting lines should be of wire or have wire cores, like the material used for leadlines. The lines shall be carefully marked and their lengths verified in accordance with instructions for the leadline (see 3–65 and 5–54).

3–110 Hydrographic clocks.—All the various events of hydrographic surveying must be correctly associated in time (see 5–95). Tide reducers, the interval between soundings and positions, and other operations are controlled by time. In EPI controlled surveys the shore stations and the ship, or ships, must use accurately coordinated clocks to govern positioning operations. Time is also very important when surveys are made in areas having a large range of tide.

On ships equipped with EDO–185 echo sounders, an electric clock should be included in the 60-cycle controlled frequency circuit to provide very accurate time. Electrical contacts for sounding a buzzer or bell at various intervals of time can be attached to the clock.

For portable use, especially in launch hydrography, it is most convenient to mount a clock on the sloping face of a box about 12 inches high with a 10-inch square base. The front of the box should slope at an angle of about 30°. The clock should be of the 8-day type with an easily read 6-inch dial and should be enclosed in a transparent-faced, nickel-plated case, arranged for mounting by means of screws through holes in the base flange. The clock should be sturdily constructed to stand hard usage and should be spray proof.

A hydrographic clock that will sound a buzzer at selected intervals is available and shall be used by launch hydrographic parties. A mechanism is attached to the clock and consists of contacts with which the second hand makes an electrical contact at intervals of 10, 15, 20, 30 or 60 seconds. The contacts are connected to the buzzer and power is furnished by dry cell batteries placed inside the box. Such a clock has the advantage of ensuring uniformity of sounding intervals and of giving the recorder more time for his other duties.

Clocks should be adjusted to keep time correctly, and any clock which cannot be adjusted to maintain correct time within 3 minutes per 24 hours should be repaired locally or returned to the Washington Office. Hydrographic clocks should be compared with a standard and set correctly at the start of each day's work and compared again at the end of the day. Camp parties should make comparisons with the standard by radio at least once each day.

Oceanographic Equipment

3–111 Oceanographic winch.—Before the advent of echo sounders, ocean depths were sounded by making vertical casts with piano wire. Because of the low breaking strength of the wire, a detachable weight was used. Oceanographic observations with the wire sounding machine were time-consuming and limited by the size of wire; however, observations were made with this type of machine in depths of 4,600 fathoms.

A winch of some type for making casts to considerable depths is an essential item of equipment for survey ships of all sizes. Oceanographic instruments have become larger and heavier creating a requirement for winches of greater lifting capability. Several expedients have been used in adapting various types of available winches to oceanographic work. These have included direct current electric drive motors and both direct and alternating electro-hydraulic drive. Because of the fine degree of control required

for deep casts, alternating current electric drive cannot be used unless complex and expensive control systems are incorporated.

An advanced type of oceanographic winch (Fig. 30) specially designed for the purpose is coming into use. The winch has electro-hydraulic drive powered by a 15 HP constant speed electric motor driving a piston-type hydraulic pump. Control is exercised by stroking the pump, i.e., varying the length of stroke of the piston. The equipment is capable of a line pull of 1,500 pounds at 300 feet per minute. The capacity of the winch drum is 30,000 feet of $\frac{5}{32}$-inch stainless steel cable. The new winch is substantially superior to the older types in that it provides greater line pull, increased retrieving speed, improved control, more protection of equipment afforded by the hydraulic system, and several safety features. The most important safety feature is the automatic overhauling device which operates as follows: when the line pull exceeds 1,500 pounds, the hydraulic fluid is vented to a by-pass and the winch overhauls at a slow speed until stopped by the brake. This prevents closer approach to the 2,200 pound breaking strength of the cable and possible loss of an expensive group of instruments or the cable which is also costly.

This is an intermediate size winch suitable for lowering small corers, cameras, Nan-

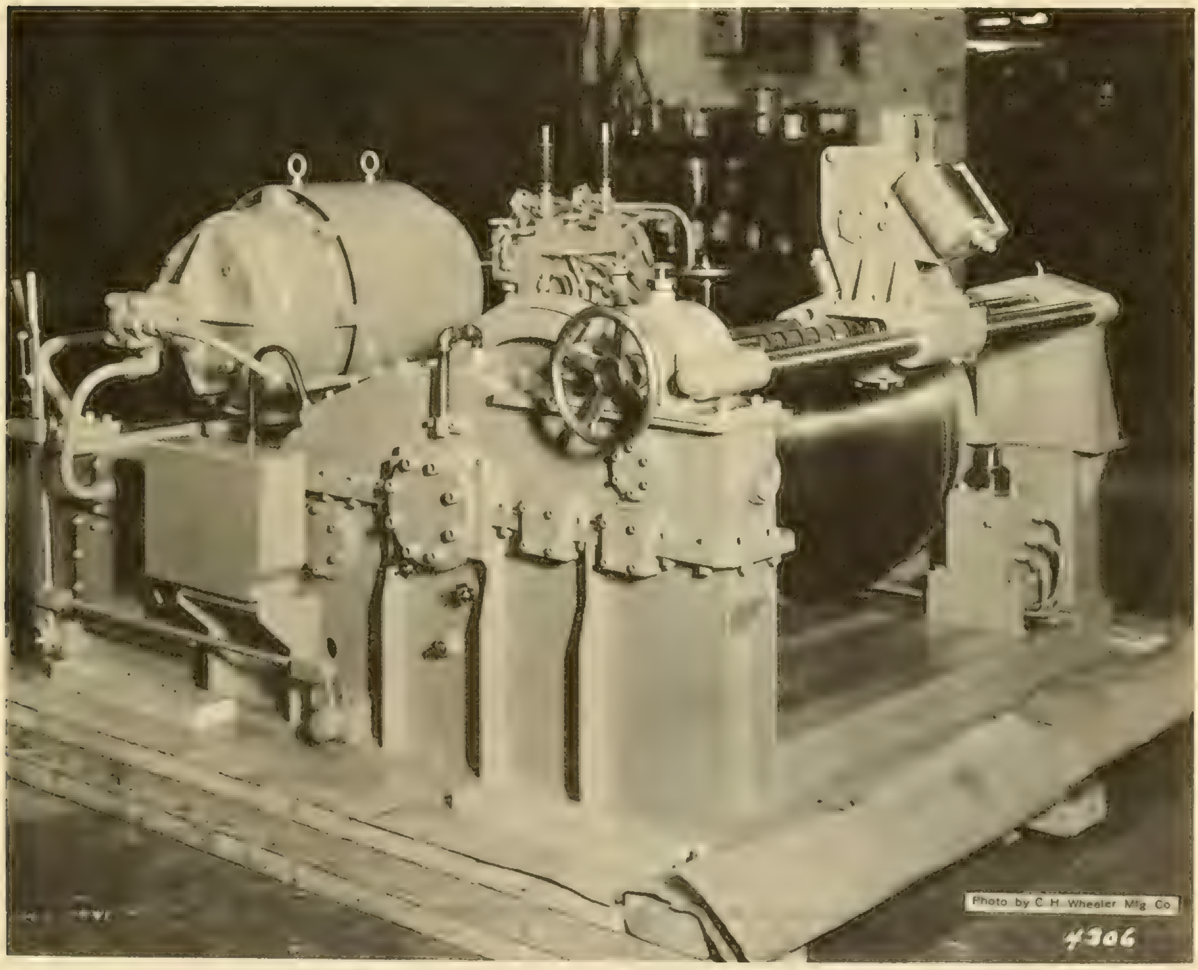


FIGURE 30.—A modern electro-hydraulic oceanographic winch with a capacity of 30,000 feet of 5/32 inch wire rope.

sen bottles, and instruments of similar size and weight. Heavy duty winches now under development will be capable of storing upwards of 40,000 feet of tapered cable (3/8 to 3/4 inch) and exerting a line pull of 30,000 pounds at 130 feet per minute. Traction devices separate from the storage drums are required. The winch will be used for obtaining large cores, deep dredging, or for anchoring in great depths.

The oceanographic winch is mounted on deck so that the cable can be lead directly outboard to an "A" frame or boom. When deep casts are made a dynamometer or ball breaker device should be used to indicate when the bottom has been reached.

3–112 Bathythermograph winch.—The BT winches now in service are powered by 3 HP single speed electric motors. This power is inadequate to utilize the full working strength of the 3/32-inch cable. The winch is being redesigned to incorporate electro-hydraulic drive powered by a 5 HP motor (Fig. 31). This will provide greater flexibility in the use of this equipment and it should be suitable as an all-purpose oceanographic winch for small survey vessels.

The winch is designed primarily for use in lowering a BT both while underway and when drifting or anchored on station. The reel will hold approximately 3,000 feet of 3/32-inch 7 × 7 stainless steel aircraft cord which has a breaking strength of 1,500 pounds. The winch may be used for a variety of purposes in appropriate depths; such as: Nansen bottle casts, bottom sampling with small samplers, lowering cameras or plankton nets, and as a sounding machine.

FIGURE 31.—Bathythermograph winch.

3–113 Dredging winch.—Any available winch may be modified to serve as a dredging winch in moderate depths of 200 to 400 fathoms. The winch should have a storage capacity of 900 fathoms of 3/8-inch cable or 500 fathoms of 1/2-inch cable and a level wind device to lay the turns evenly on the drum. A power supply sufficient to exert a pull of about 5,000 pounds is required. There should be an indicator to show the amount of cable paid out.

Two methods have been used on C&GS ships to provide a dredging winch which meets the above requirements. The wire rope drum on the anchor windlass may be adapted for the purpose, or a boat hoisting winch may be used. See Section 3–131 for a description of dredges.

3–114 Bourdon type bathythermograph (BT).—The bathythermograph (Fig. 32) consists essentially of a thermal element and a pressure or depth element so constructed that a staballoy coated or smoked glass slide driven by the pressure element moves at right angles to a stylus which in turn is driven by the thermal element. A trace showing temperature with relation to depth is drawn on the slide as the BT is lowered and raised.

The BT may be lowered while underway or when lying to on station. BT's are furnished for three ranges: 200 feet, 450 feet, and 900 feet. A BT should never be lowered deeper than its designed range. BT slides shall be marked and lacquered in accordance with instructions contained in the manual furnished with each BT.

A special grid is supplied for each instrument for converting the stylus trace to temperature and depth readings. These grids

FIGURE 32.—Bourdon type bathythermograph.

are not interchangeable between instruments, since each grid is calibrated for a particular BT. Never let the temperature of the BT exceed 105° F. At this temperature the stylus brings up against a stop pin; if this temperature is exceeded, permanent deformation of the brass coil in the Bourdon will occur and the calibration of the instrument will be ruined.

In addition to the manual furnished with each BT, observers should study Sections 2–32 to 2–59, inclusive, of H.O. Pub. No. 607, Instruction Manual for Oceanographic Observations.

3–115 Reading BT slides in the field.—The lacquered BT slides and log sheets shall be forwarded to the Washington Office at the end of the season. When project instructions require it, the BT slides shall be scanned in the field and the data recorded on Form 732, Field Record of BT Data (Fig. 33), as follows:

Insert the slide in the proper grid. Record the slide number, date and time of observation, surface temperature as observed with the bucket thermometer, and the distance in feet that the BT trace terminates above (a) or below (b) the zero depth line on the viewing grid. Record the surface temperature (temperature at the top of the trace) as shown by the BT. In the first column at the left of the form enter, from top to bottom, decreasing temperature values at one-degree intervals to cover the range of temperature to be recorded from that slide. With the BT slide firmly in place in the viewing grid, read and record in the second column the depth at which each degree of temperature is encountered. No corrections shall be made. At the bottom of each column record the temperature and depth of water at the lower end of the trace. If a temperature inversion is observed, use extra columns as may be needed and as shown in the illustration.

BT slides, BT log sheets, and Forms 732 shall be forwarded to the Washington Office in separate mails.

3–116 Temperature and salinity observations.—Nearly all hydrographic parties are required to measure the temperature and salinity of sea water either as part of a program of oceanographic observations or to obtain data for determining the velocity of sound. In the latter case, the data are required to correct echo soundings when the calibrated velocity of the sounder differs from the actual velocity (see 5–114). The program of observation involves measurements from the surface to the bottom at intervals which will permit drawing accurate temperature and salinity curves.

The International Association of Physical Oceanography, in 1936, proposed the following standard depths at which observations

FORM 732
(2-11-59)

U.S. DEPARTMENT OF COMMERCE
COAST AND GEODETIC SURVEY

FIELD RECORD OF BT DATA

YEAR *1958*

VESSEL *Ship HYDROGRAPHER*

CHIEF OF PARTY *G. R. Fish*

GENERAL LOCATION *South of Georges Bank*

(TEMPERATURE IN °F DEPTH IN FT.)

SLIDE NO.	2	3	4	5	5	5	5	6	6	6	6						
DATE	8/8	8/8	8/8	8/8				8/9									
TIME	2100	2200	2300	2400				0100									
SRF. TEMP. (BUCKET)	64.8	61.2	63.5	67.0				68.4									
SRF. TEMP. (BT)	64.5	61.0	63.2	66.8				68.0									
*TRACE FT. a OR b	1a	0	1b	2b				1b									
TEMP	DEPTH							Temp	Depth								
65				30 36				68	Surf.								
64	15			38				67	40								
63	22		5	44				66	43								
62	30		20	60				65	50								
61	35		24	78				64	57								
60	37	30	25	80				63	60								
59	38	32	28	80				62	65								
58	40	37	29	80				61	72								
57	44	40	30	100				60	77								
56	48	47	35	108				59	78								
55	50	53	39	108				58	79								
54	52	61	42	110				57	80								
53	55	70	43	112				56	81								
52	60	81	46	114				55	90	280	300						
51	70	110	48	116			440	54	98	270	360						
50	72	140	50	118			420	53	99	268	420						
49	77	180	60	120			410	52	118	265	540						
48	90		70	135	170	270	380	51	125	257	590						
47	130		110	150		240 340		50	142	252	630						
46	152		250	160				49	165	245	680						
								48	175	235							
								47	185 220	230							
BOTTOM TEMP (BT)	45.8	49.0	46.0				50.5				49.0						
BOTTOM DEPTH (BT)	170	190	270				490				690						

*INDICATE NUMBER OF FEET BT TRACE TERMINATES ABOVE (a) OR BELOW (b) SURFACE LINE ON VIEWING GRID.

USCOMM-DC 27308-P

FIGURE 33.—Sample field record of bathythermograph data, Form 732.

should be taken directly or the data adjusted by interpolation from the distribution at other levels. The standard depths, in meters, are: 0, 10, 20, 30, 50, 75, 100, 150, 200, (250), 300, 400, 500, 600, (700), 800, 1000, 1200, 1500, 2000, 2500, 3000, 4000, and thence at 1000 meter intervals to the bottom. The depths in parenthesis are optional. Refer to H.O. Pub. 607 for detailed instructions covering observation procedures.

Several factors influence the spacing of sample bottle depths, particularly in the upper layers, in turbulent water, and in areas of upwelling or where temperature inversions occur. It is desirable to determine the temperature curve accurately from surface to bottom. A BT lowering to maximum depth should be made at each oceanographic station. The BT trace will show temperature gradients, disclose the existence of inversions, and assist in selection of appropriate depths for sampling. Steep gradients may require closer spacing of the bottles.

Because oceanographic data are assembled from many sources on a nation-wide basis and processed by machines, it is desirable to use the International Standard Depths. When serial temperatures and salinities are observed for correction of soundings in relatively small project areas and the registering sheave is graduated in fathoms, observations should be taken at the following approximate depths: 0, 2, 10, 20, 30, 50, 75, and 100 fathoms.

3–117 Protected reversing thermometers. —Two types of protected reversing thermometers are used by the Coast and Geodetic Survey. One has a scale graduated to 0.2 degree C. and without an enclosed auxiliary thermometer. It is used in a Tanner-Sigsbee Reversing Frame. The second type is somewhat larger, is graduated to 0.1 degree C., is accurate to a few hundredth of a degree, and has an auxiliary thermometer enclosed (Fig. 34). This is a more precise thermometer and should always be used in Nansen Bottle casts at oceanographic stations. Requisitions for protected reversing thermometers should state the type desired—that is,

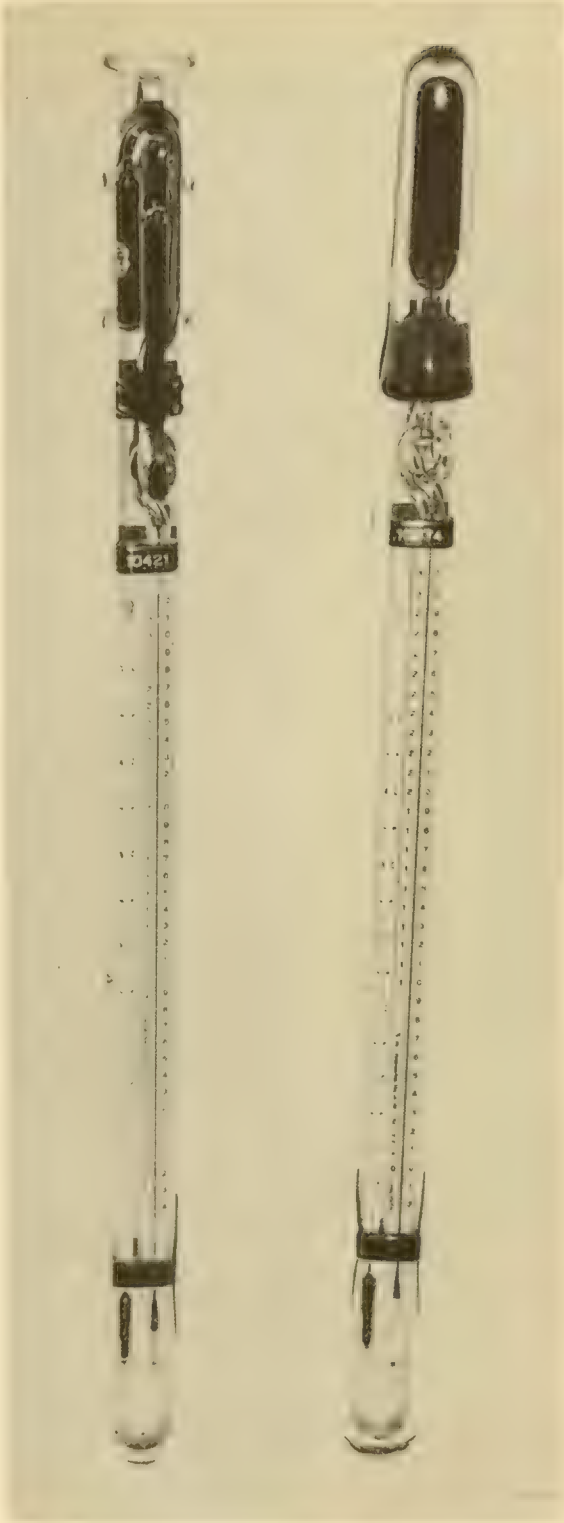


FIGURE 34.—Precision type deep sea reversing thermometers, unprotected on left, protected on right.

for use in Nansen bottles, or Tanner-Sigsbee reversing frames.

Reversing thermometers are delicate instruments and must be handled with extreme care at all times. A protected thermometer is enclosed in a heavy glass case sealed at both ends to protect it from pressure of the water. The special features of a reversing themometer are: a knife-edge in the capillary tube which is made by an appendage in the tube; a gooseneck which may take the form of a U-turn, S-turn, or a complete circle, and a supplementary mercury reservoir at the opposite end from the main reservoir.

When the thermometer is reversed, or inverted, the extra weight of the mercury in the enlarged section of the capillary tube in the gooseneck breaks the mercury column at the knife-edge, the mercury flows into the supplementary reservoir, and extends into the graduated stem where the temperature is read when held in an inverted position. Thus, when the thermometer is reversed in watei at any depth, the temperature at the point of reversal is obtained. Since the jacket protects the thermometer from hydrostatic pressure a true reading of temperature can be made. If the thermometer does not have an auxiliary, the temperature should be read as soon as possible after it is brought to the surface.

3–118 Unprotected reversing thermometers.—An unprotected reversing thermometer is similar to the protected type in most respects except that one end of the glass jacket is open. The thermometer is in direct contact with the water and is subject to hydrostatic pressure. It has no mercury surrounding the reservoir as does the protected thermometer. It does not give a true temperature reading but gives a reading which increases in direct relation to the depth. By pairing a protected and an unprotected thermometer on one Nansen bottle the temperatures can be used to determine the depth at which the thermometers were reversed.

3–119 Care of thermometers.—Deep-sea reversing thermometers are expensive instruments. Each one must be carefully calibrated at considerable additional expense. Unless they are properly handled the mercury column may be separated by gas bubbles in the capillary and the calibration lost. The following rules should always be observed when using these instruments:

(a) Avoid laying a reversing thermometer in a horizontal position.

(b) When not in use, each thermometer should be placed in its individual cylindrical case and stored in a padded carrying case with the large mercury reservoir down. Always keep the carrying case in an upright position.

(c) All thermometers should be washed in fresh water and dried before storing them in the case.

(d) Handle them gently, if the mercury fails to return from the supplementary reservoir a light tap with the finger will bring it down.

(e) Never store the thermometers in the Nansen bottle frames. If the thermometers are left in the Nansen bottle frames during a run between stations, the bottles should be placed in the storage rack with the large mercury reservoirs down.

3–120 Corrections to observed temperatures.—A calibration certificate is furnished with each reversing thermometer from which graphs can be drawn and corrections scaled as needed. Precisely measured temperatures are not required for computing corrections to echo soundings, however, observed temperatures should be corrected from the calibration graph and the final results should be accurate to one or two tenths of a degree. Observed temperatures may contain small errors from two different sources. One of these is an intrinsic error of the thermometer due to slight irregularities in the capillary tube and slight errors of graduation. Corrections for these errors are determined by calibration. The calibration curve retains its shape but moves slightly with respect to the freeze point and with age until the glass becomes stable.

The other error is due to the change in the volume of mercury contained in the

capillary tube and the small reservoir caused by the different temperature of the surrounding air after the thermometer is brought to the surface. The amount of this correction is computed from the auxiliary thermometer reading on precise thermometers. A detailed discussion of methods for computing these corrections is contained in H.O. Pub. No. 614, Processing Oceanographic Data.

3–121 Nansen bottles.—The Nansen bottle (Fig. 35), is a cylindrical metal reversing sampler with a capacity of 1.25 liters (2.25 pints). Each end of the tube is fitted with slit valves which operate synchronously by means of a connecting rod. The rod joins the clamping and releasing mechanisms. Nansen bottles are used with the oceanographic winch to obtain water samples and temperatures at any depth. They may be used in more limited numbers and in comparatively shoal depths with the BT winch.

Each Nansen bottle is fitted with a frame to hold two reversing thermometers. Brass tubes in the frame are slotted to permit easy reading of the thermometer scale. One end of the tube is perforated to permit circulation of the water around the thermometer. The large reservoir end of the thermometer is placed at this end of the tube. Rubber pads backed by helical springs are fitted in each end of the tube to hold the thermometer in place and to guard against shock.

Nansen bottles should be carefully checked before they are used to see that all moving parts are properly greased and move freely. Close the air vent and draincock, secure the bottle to the wire with the clamp and fulcrum assembly at the bottom. A messenger must be attached to all but the lowest bottle on the cast. Before lowering the bottle, check to see that the mercury in each thermometer has drained down to the main reservoir.

Not more than 12 Nansen bottles should be used on one cast with $\frac{5}{32}$-inch wire, and not more than 5 should be used with the BT cable. As the bottles are lowered a flushing action takes place, but they will carry some water down with them. After the bottles are lowered to the desired depths they should be

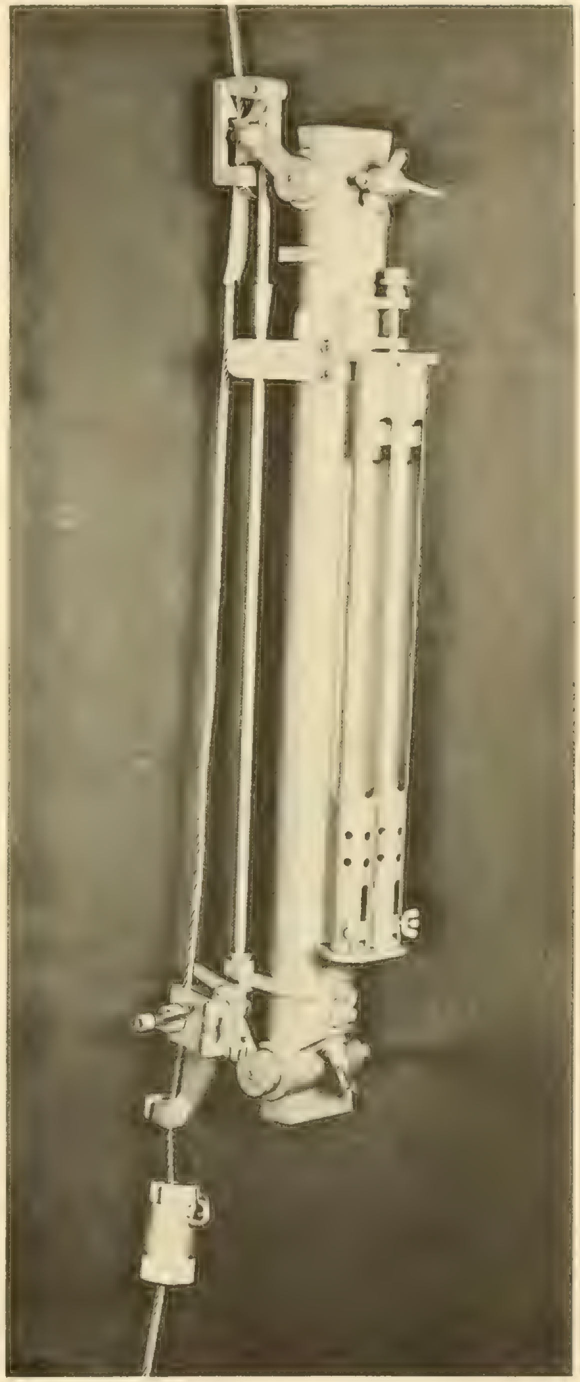


FIGURE 35.—Nansen bottle.

permitted to stand for a minimum of 6 minutes in order that the thermometers may register correct temperatures and the flushing of the bottles completed. A messenger is then dropped to the first bottle. The wire angle should be measured just before or after the messenger is released. It releases the mechanism at the top of the bottle allowing it to fall away and reverse its position at the same time closing the valves trapping a water sample. The messenger on that bottle is released and the action repeated successively to the bottom. A messenger will fall at a rate of 150 to 200 meters per minute depending on the angle of the wire. Do not begin hauling in the cast until the bottom bottle has been reversed.

The winch should always be started slowly and with due regard to the rolling of the ship. A sudden jerk or undue strain may part the cable and a valuable group of instruments will be lost.

3–122 Water samples.—Each Nansen bottle is detached from the cable, as it reaches the surface, and placed in a rack constructed for that purpose. Water samples are drawn into glass bottles and the thermometers are read. The water samples may be analyzed for such constituents as salinity, dissolved oxygen content, or various nutrients. Detailed instructions for drawing and preserving water samples are contained in H.O. Pub. 607. If salinities are desired for echo sounding corrections only, the sample may be drawn in a hydrometer jar and the specific gravity measured by a hydrometer.

If the samples are titrated to determine chlorinity, the salinity may be determined as follows:

Salinity $=0.03+1.805\times$ chlorinity °/00 or by reference to Table 16 in H.O. Pub. 607.

3–123 Tanner-Sigsbee reversing frame.—The Tanner-Sigsbee reversing frame (Fig. 36) is designed for only one thermometer, which is held in a slotted metal tube holder by means of rubber cushions backed by a helical spring at each end. The lower end of the holder is hinged to the bottom of the frame, the upper end being held in place by a pin. The thermometer is placed in the tube with the reservoir at the hinged end.

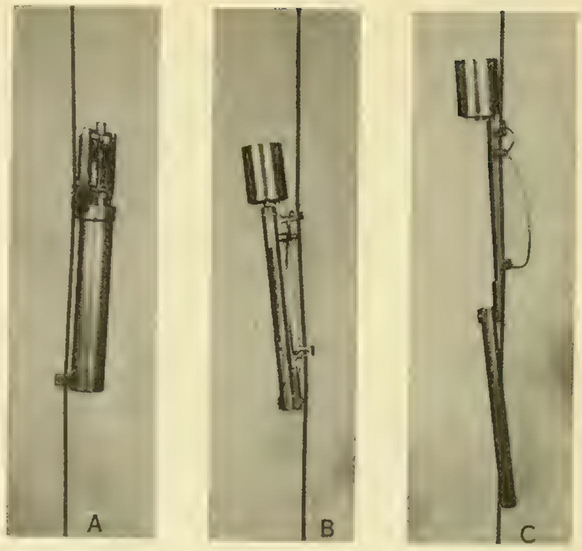


FIGURE 36.—A. Improved Sigsbee watercup. B. Tanner-Sigsbee reversing frame and reversing thermometer in position to lower. C. Tanner-Sigsbee frame with thermometer reversed.

The pin at the top is the lower end of a coarse-threaded shaft to the top of which a propeller is attached. The blades of the propeller are arranged so that downward passage through the water forces the pin into a small hole at the top of the holder, maintaining it upright, but as soon as the frame is drawn upward, the propeller revolves withdrawing the pin from the hole so that the holder is free to capsize. The frame is secured to a sounding line, or a short section of manila line, by means of a strong spring which clamps at top and bottom. It must be placed in such a position that the holder, when reversed, will not strike the lead or another instrument below it.

This frame should not be used when the vessel is rolling or pitching as the propeller acts very quickly to release the holder and causes reversal before the thermometer can adjust to the temperature of the water. If the thermometer has been lowered below the intended depth no attempt should be made to adjust the depth.

3–124 Sigsbee watercup.—The Sigsbee

watercup (Fig. 36) is an efficient instrument for collecting water samples at any depth. It is similar to the Tanner-Sigsbee reversing thermometer frame in the way it is attached to the sounding line and in that a propeller is employed to hold the valves closed. There are two poppet valves on the watercup, one at the top and one at the bottom, which are connected by a rod through the axis of the cylinder so that the valves open and close simultaneously. The propeller is mounted at the top and revolves freely on descent allowing the valves to remain open and water to pass through the cup. The valves close when the downward motion ceases, and, as the cup is drawn upward, the propeller engages a clutch which clamps the valves in the closed position. When draining the water into the hydrometer jar, the locking device should be unscrewed all the way and the valve lifted quickly with the fingers, otherwise the water will spray in all directions around the jar.

3–125 Hydrometer sets.—The method usually used by the Coast and Geodetic Survey to determine the salinity of seawater is to measure the specific gravity of the water sample with a hydrometer. If the specific gravity is known, the salinity may be found by the use of tables or a graph. The temperature and specific gravity of a water specimen are measured with a hydrometer set consisting of a hydrometer jar, a laboratory centigrade thermometer, and a set of three hydrometers graduated for different ranges of specific gravity. These are illustrated in Fig. 37.

FIGURE 37.—Hydrometer set.

A glass hydrometer has a small graduated stem and a bulb counterweighted for the range of graduations. They are very fragile instruments and must be handled carefully to prevent breakage. Hydrometers are furnished in sets of three, graduated for the following ranges of specific gravity: 0.9960 to 1.0110; 1.0100 to 1.0210; and 1.0200 to 1.0310. Hydrometers are compared with standards maintained at the Washington Office, and no hydrometer will be furnished which is not correct to 0.0002 of specific gravity. Observed specific gravity may be used without correction for calibration errors.

Hydrometers are graduated to indicate specific gravity at a standard temperature of 15° C., referred to the specific gravity of fresh water at a temperature of 4° C. as unity. Salinity tables are computed on this basis.

3–126 Specific gravity measurements.—A sufficient quantity of the water specimen should be poured in the jar to float the hydrometer without touching the bottom. The jar may be placed on a level bench or shelf, or held in the hand if there is excessive rolling. If held in the hand, it should be grasped near the top and held between the thumb and one finger so that it can swing freely. Float the hydrometer and rotate it slowly, insert the thermometer and watch the mercury column until it comes to rest. The hydrometer should float freely without touching the sides of the jar. With the eye nearly level with, but slightly below the water level in the jar, the surface of the water will be seen as a straight line intersecting the graduations on the hydrometer stem. The water temperature should be observed and recorded at once. Disturb the hydrometer and repeat the observations as soon as it comes to rest.

If the samples are to be preserved for laboratory analysis, they should be stored in citrate bottles properly labeled and identified. Observed densities and temperatures may be converted to salinity by reference to

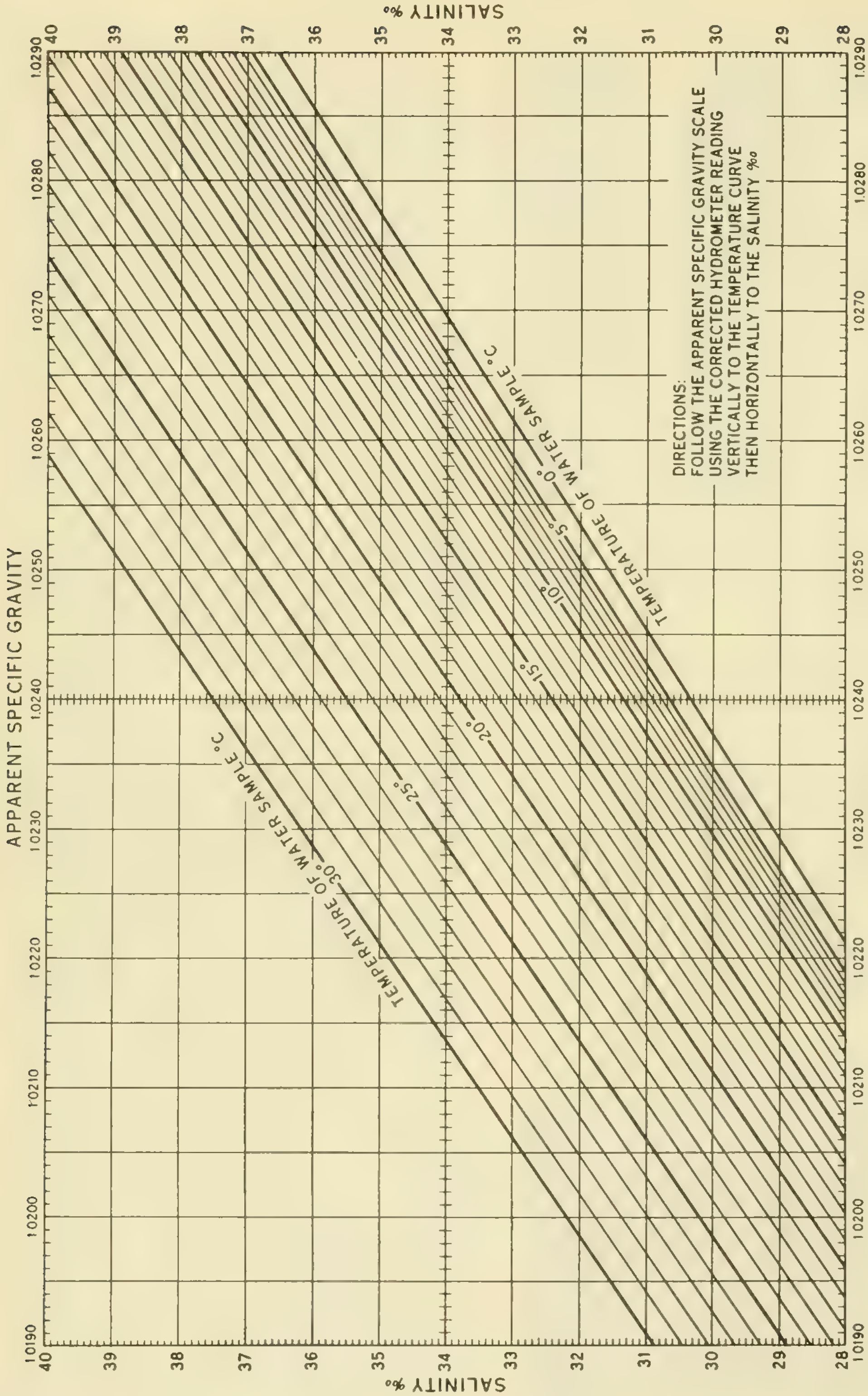


FIGURE 38.—Graph to convert apparent specific gravity to salinity.

a graph, Figure 38, or by use of tables in Special Publication No. 298, Sea Water Temperature and Density Reduction Tables.

3–127 Bottom samples.—A device to obtain samples of bottom materials is required so that bottom characteristics may be shown on the nautical chart (see 5–76). The mariner, and consequently the hydrographer, is interested solely in the material on the surface of the bottom. Minimum requirements for bottom sampling are stated in 1–42. An armed lead or snapper type sampler will provide the necessary data for charting purposes. Sampling for oceanographic studies requires the use of other instruments such as dredges or corers. Bottom sampling instruments used by the Coast and Geodetic Survey are briefly described in the following paragraphs.

3–128 Clamshell snappers.—Nearly all bottom samples in hydrographic surveys are obtained with a snapper-type device (Fig. 39). The armed sounding lead is used infrequently in shallow water. The snapper type of sampler has two clamshell jaws that are held open by an interior trigger, held in place by the pressure of a compressed helical spring around the shank of the instrument. The trigger is formed of two metal pieces hinged on the inside of each jaw. When the open jaws strike the bottom, the trigger is released and the tension on the spring closes the jaws around a portion of the material on the surface of the bottom. If the bottom material is rocky, no sample will be obtained but the cup will usually be scratched or dented slightly. In gravel bottom the jaws may close on small pebbles and the sample will be washed out as the cup is retrieved.

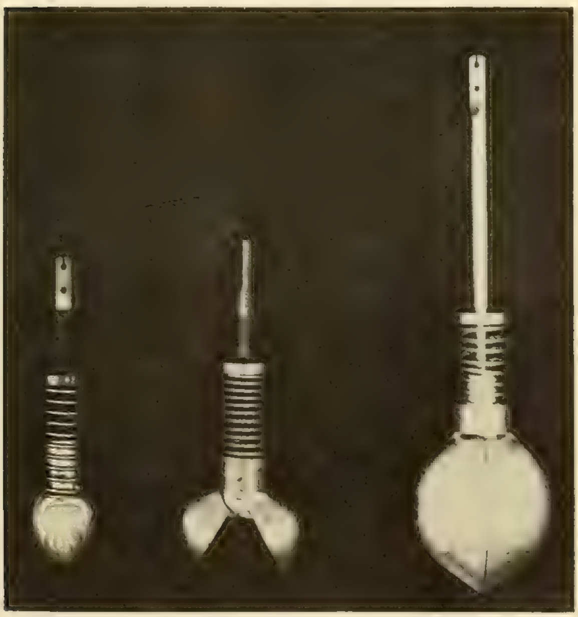


FIGURE 39.—Snapper type bottom sampling devices.

The correct adjustment of the tension of the spring is important and must be reached by trial. When the tension is correct, the trigger will always be released when the jaws strike the bottom and the jaws will be held firmly closed. The tension may be increased or decreased by moving a nut, which compresses the spring, along a screw thread on the shank.

The shank of the sampler extends above the spring so that it can be inserted and riveted in a sounding lead. Snappers are available from the Washington Office in three sizes with capacities of approximately 15, 90, and 500 cubic centimeters. The various sizes should be used with sounding leads of appropriate weights. A lead weighing 35 pounds or more should be used in deep water. The small samplers are adequate for hydrographic surveys, and the large one should be used only when samples are to be retained for analysis.

3–129 Scoopfish sampler.—The scoopfish bottom sampler, (Fig. 40) is designed to obtain bottom samples in depths less than 100 fathoms while the ship is underway. The sampler weighs 11 pounds, is 15 inches long, and is lowered from the BT winch. It should be lowered slowly until close to the surface of the water and then dropped. Unless this is done the nose lid may be released as the scoopfish enters the water. When the sampler strikes the bottom, the cup is pushed back, releasing the nose lid which closes over the sample, and the towing arm is rotated forward.

After retrieving the scoopfish, the cup and sample are removed, another cup is inserted

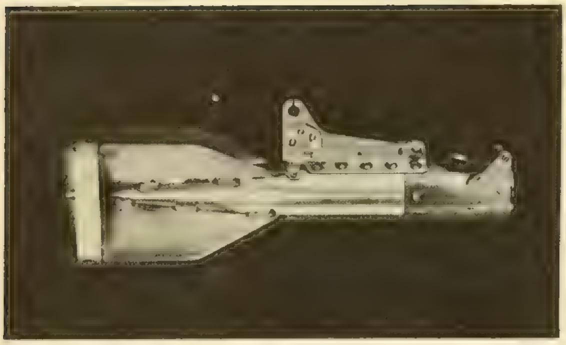


FIGURE 40.—Scoopfish bottom sampler.

and the procedure can be repeated. After lowerings have been completed, the instrument should be washed with fresh water and all moving parts given a coat of light machine oil.

3–130 Phleger corer.—The Phleger corer (Fig. 41) is used to obtain cores about 12 inches in length, and may be used to obtain cores 36 inches long. The corer consists of a cylindrical core barrel with a cutting bit and core catcher, an upper tube with spring, check valve, and tail fin assembly, and about 40 pounds of lead around the barrel to provide driving thrust. Plastic liners, 1½ inches outside diameter, are used to hold the cores.

The Phleger corer is used with the oceanographic winch. It may be used with the BT winch in depths less than 50 fathoms. In medium soft bottom and depths less than 30 fathoms, full length cores can be obtained without using the detaching device. In greater depths, this mechanism should be used. When the detaching device is used, it is attached to the hoisting cable and carries the weight of the corer during descent. A tripping line about 18 feet long is attached to the arm, and a 14-pound sounding lead is attached at the other end of the line. The corer is secured to the detaching mechanism by a 20-foot section of 3⁄16-inch chain.

The instrument is prepared for use by inserting a section of plastic tube of proper length in the coring tube, then the core catcher and cutting bit are inserted and secured. The corer is then attached to the release mechanism and lowered away. The

FIGURE 41.—Phleger corer in position for lowering.

cores should be preserved intact in the plastic tubes, each end of the tube being corked or covered by a plastic cap, or by extruding the sample into ball-mason jars. Each sample must be properly logged and identified.

Various other devices have been used to obtain bottom cores at all depths. The Kullenburg piston corer is capable of taking cores 12 feet long, and the Ewing piston corer can take a core from 20 to 75 feet in length. The Kullenburg corer can be used with 5⁄32-inch wire in limited depths and without using the free fall feature. The Ewing corer requires much heavier equipment.

3–131 Dredges.—Dredging is generally confined to the continental shelf because of the weight of gear required. A sturdy winch and cable of at least 3⁄8-inch diameter is required. Dredging must be done at slow speed, and can be done by drifting with the wind or current. The dredge samples the surface layer and will trap large stones

which cannot be taken by other types of samplers.

Dredges are of various designs. A section of 10- or 12-inch steel pipe about 3 feet in length can be used. One end of the sampler is closed by welding steel bars across it so as to retain large specimens. Wire mesh screens of various size openings may be used in the bottom of the dredge to retain samples of any desired minimum size and the finer sediments will be washed out.

Another type of dredge is constructed of ¼-inch steel plate, and is 1 foot deep, 2 feet wide, and 3 feet long. The bottom is closed and screened as above.

A third type is constructed of a rectangular steel collar to which is attached a purse of chain mail (Fig. 42). Interior of the purse may be lined with screens as in the other dredges or with netting, shrimp net being commonly used.

If specimens of the sediment or other fine particles are desired, a small section of 2-inch pipe with a canvas bag at one end may be towed behind the dredge.

FIGURE 42.—Chain mesh dredge.

It is advisable to rig the dredge with a short section of chain above the bridle which is hooked to a weak link. Another cable shackled above the weak link leads to the after end of the dredge. If the dredge fouls on fast rock, the weak link will break, the second cable will dump the dredge and clear it from the bottom.

The samples should be transferred to water-tight containers, labeled and stored or shipped in accordance with instructions.

3–132 Other oceanographic instruments.—In recent years, oceanographic and electronic laboratories have developed new types of instruments for measuring temperature, salinity, and velocity of sound *in situ*. New designs in camera equipment permit the taking of a series of photographs at one lowering to the ocean floor. Most of these instruments require a source of power at the ship, or furnish information on dials aboard the ship, which requires the use of multiconductor cables. The maximum depth at which the instruments can be used is governed largely by the length of cable which can be used, or by the pressures which the instrument will withstand. A few of these equipments are briefly described in the following paragraphs.

3–133 Induction Conductivity Temperature Indicator (ICTI).—The ICTI was developed by the Chesapeake Bay Institute for use in oceanographic studies in estuaries and other shoal water areas along the Atlantic Coast. The instrument measures conductivity and temperature *in situ* and salinities can be computed from these data. The ICTI consists of shipboard indicators, an underwater unit for measuring conductivity, a resistance thermometer, and a connecting cable (Fig. 43).

In the conductivity unit, there are two coaxially mounted iron-cored inductors which are insulated from the water. The first cores winding is connected to 115 V 60 cps, so that a low voltage will be induced in any one turn link which threads the hole in this core. The total current flowing through the hole is proportional to the conductivity of the

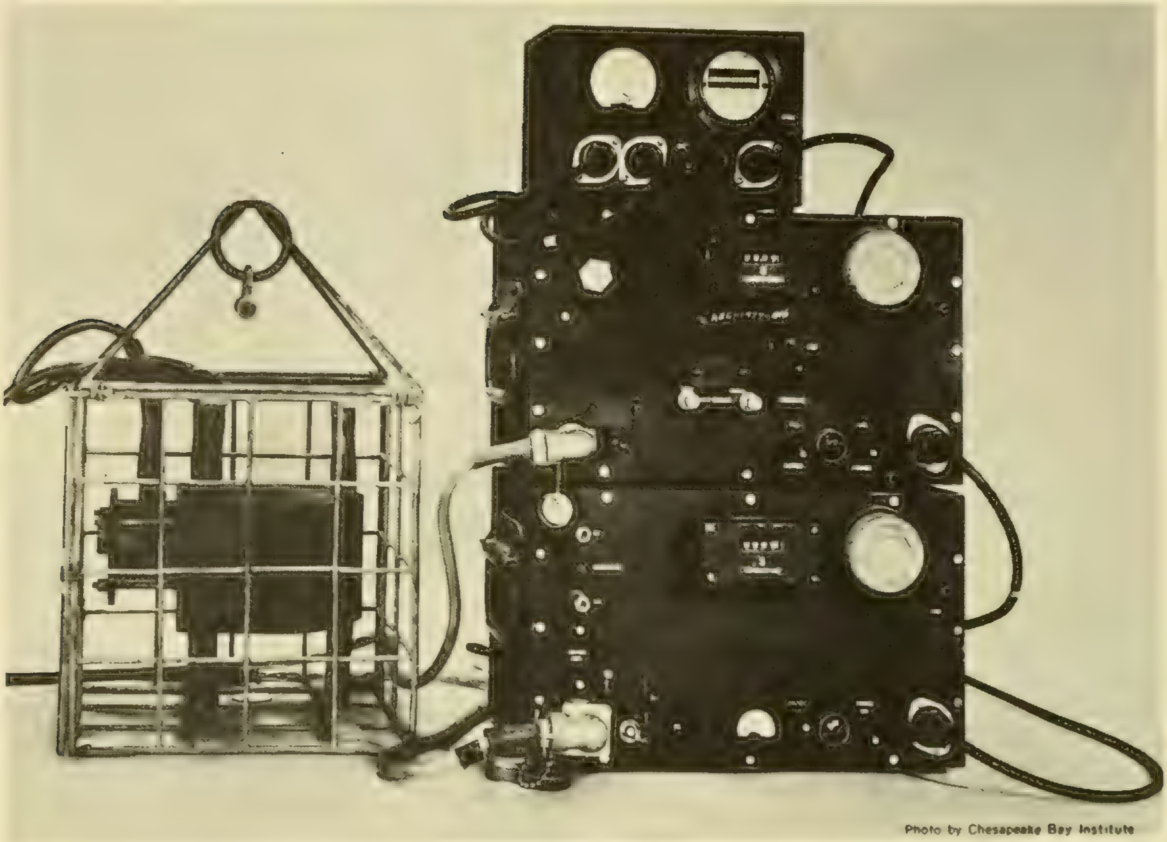


FIGURE 43.—Chesapeake Bay Institute ICTI.

water in which the transformer is immersed. This current is measured by the second core, and the output signal is transmitted, along with a reference voltage derived from a secondary winding on the first core, through the cable to the indicator aboard ship, where the information is automatically processed and actuates a counter so that conductivity is read directly. The conductivity reading and the simultaneously observed temperature are used to enter tables from which salinities are extracted.

The temperature sensing element is a resistance thermometer, made from about 25 feet of enameled nickel wire wound around a tube and connected to the cable. The temperature measuring circuit is a modified Wheatstone bridge. Temperature is shown directly on a dial to 0.01° C.

3–134 Salinometer (salinity bridge).— The Salinometer, or salinity bridge (Fig. 44) is an instrument for the determination of salinity of sea water aboard ship or in the laboratory by an electrical conductivity method. The first apparatus of this kind was constructed by the National Bureau of Standards in 1930 and is known as the Wenner-Smith-Soule Salinity Bridge. Several improvements have been made in the equipment, the most recent being described in Technical Report No. 61 published by the University of Washington in 1958.

The equipment consists of the bridge-oscillator detector unit, a refrigerated oil-tight constant-temperature bath, seven conductivity cells mounted in the bath, a refrigerator unit and controls, a proportional-type temperature controller, a constant-voltage supply for the electronic parts, and a suction system for emptying the cells.

The salinometer is calibrated in the laboratory by a lengthy series of measurements of

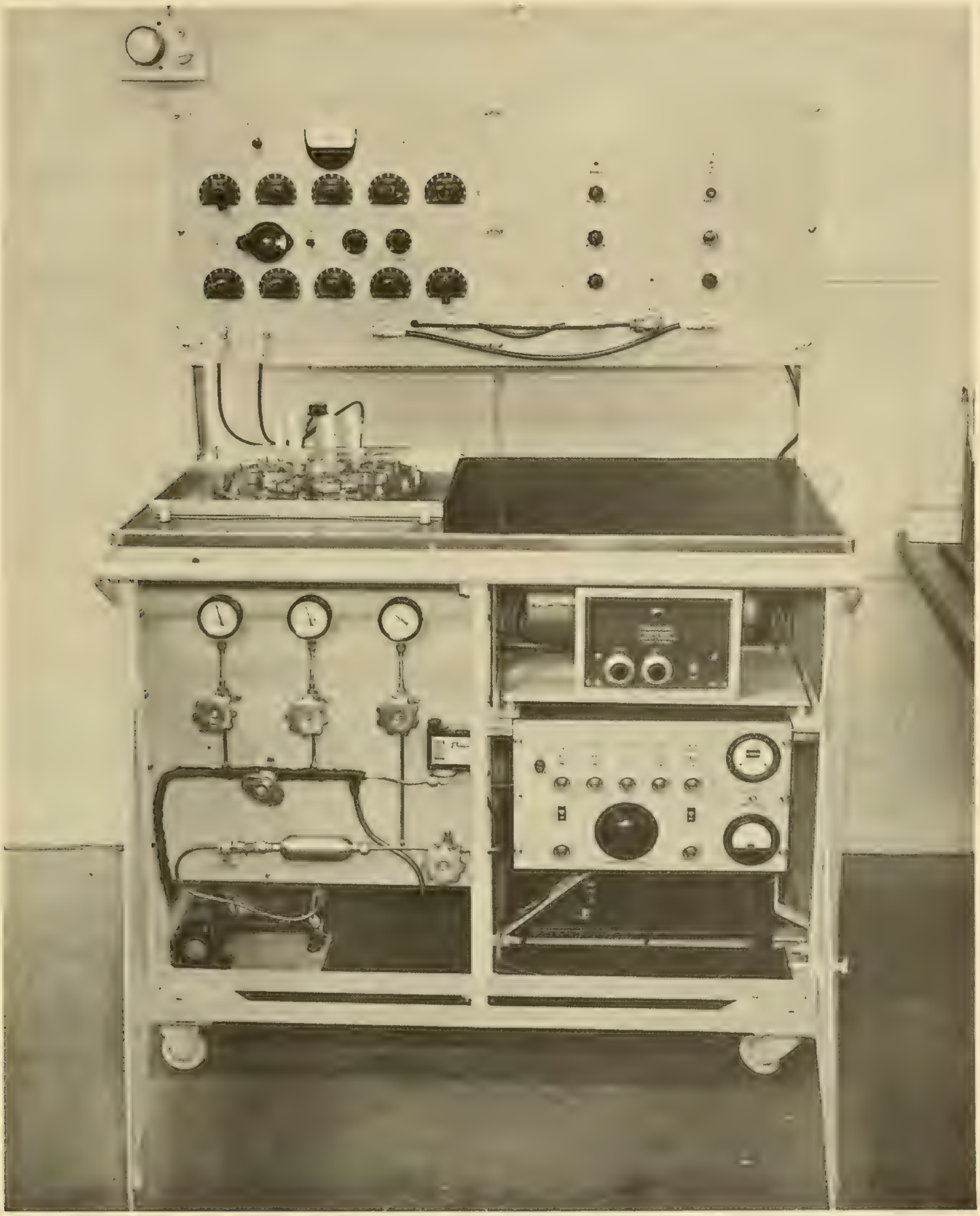


FIGURE 44.—Salinity Bridge.

Copenhagen water and other carefully prepared standard solutions whose salinities have been determined by repeated titrations. The final calibration may be expressed in graphic form at a large scale, or a salinity-versus-resistance table may be computed. How often the calibration must be renewed is uncertain but should probably be done annually.

When in use to measure salinities, one cell, called the reference cell, is filled with substandard sea water whose salinity has been determined by careful titration and the six measuring cells are filled with water from the samples. About 20 minutes are required to bring them to temperature equilibrium before measurement can begin. One of the measuring cells is then balanced on the bridge with the reference cell, the resistance reading is recorded and the procedure repeated with each of the six cells. Each sample is measured twice but in different cells. Salinities are obtained from the graph or tables using the resistance reading as an entering argument.

The reference cell and water are compared with a standard daily or more frequently if the salinity drift requires it.

When properly used the results are far more accurate than titrations at sea, salinity determinations can be made more rapidly, and the equipment can be satisfactorily operated with less-skilled personnel.

3–135 Velocimeter.—The velocimeter is an instrument devised by the National Bureau of Standards for measuring the velocity of sound in a liquid. Following this design the Coast and Geodetic Survey has built an experimental velocimeter, Model TR–2 (Fig. 45).

The velocimeter consists essentially of a sounding head or "fish," a conductor cable to suspend the instrument, and a ship-board indicator. Two small transducers and two reflectors are mounted on one end of the "fish" to form a sound path of fixed length. A signal from the sending transducer travels through the water to the receiving transducer where it is amplified to retrigger the pulse generator and start the cycle again. The system, called "sing around," continually

FIGURE 45.—Velocimeter.

regenerates a sound pulse whose repetition rate, or frequency, depends on the time it takes for the pulse to move through the water. The time required for the signal to pass through the internal circuit is fixed and can be determined by laboratory calibration. Therefore, variations in time required to make the complete cycle will be a function of the speed of sound in the liquid.

The frequency of completed cycles is shown on an indicator aboard ship. The observed frequency is used to enter a table or graph from which velocity of sound at that point is extracted. Close approximation of velocity may be obtained by multiplying the frequency reading by a constant for the velocimeter. For Model TR–2, this constant is 0.20613.

The fish is lowered by the electrical cable which must be marked or run over a registering sheave so that readings can be obtained at known depths. More complicated systems contain depth measuring elements and record velocity and depth on a tape. Velocity measurements can be made as rapidly as the instrument can be lowered and frequency readings recorded.

Although the instrument has been tested for a pressure of 16,000 pounds per square inch, it is not used in depths where such high pressure will be encountered. Its most useful range is about 0 to 50 fathoms.

3–136 Improvements in oceanographic instruments.—Bathythermographs record temperature versus depth but to a limited depth and with a temperature sensing element which is not sensitive enough to record the variations frequently encountered. The scale is also very small. Various devices are undergoing development to provide more accurate and detailed temperature profiles and to much greater depths. A thermistor is used as the temperature sensing element in some cases, thermocouples, and transducers in others. Some instruments combine temperature measuring and depth measuring units.

Designs of oceanographic winches are being studied and improved. Methods of sampling water and the bottom, underwater photographic equipment, and instruments for measuring deep ocean currents are all undergoing study.

3–137 Drafting instruments.—Small drafting instruments are an essential part of the equipment of every hydrographic party. Rolling of the vessel, exposure to spray and salt air, and the variety of circumstances under which they are used all contribute to the likelihood of damage to or deterioration of such instruments. Launch parties are furnished a sturdy box for storing small instruments, pens, pencils, and ink when not in use. Aboard ship such instruments when not in use should be stored in appropriate places and not left on the plotting tables. They should always be kept clean, free from rust, and in good repair.

The supply of small instruments for a hydrographic party should include the following:

1—Ordinary divider, 1 spacing divider, 1 drop-bow pen, 1 pricker.

1—Ruling pen, 1 opisometer, 1 quarter meter scale and 2 or 3 small plastic triangles.

3–138 Meter bar.—Scales used for constructing projections and for plotting stations or distances on hydrographic sheets are graduated in the metric system. The standard scale is the meter bar (Fig. 46) so called because its graduated scale is 1 meter in length. It is made of German silver and graduated with great precision. It is graduated on one side at a scale of 1:10,000 and on the reverse side at a scale of 1:20,000. All meter bars acquired in recent years have been tested for accuracy and calibrated by the National Bureau of Standards. A copy of the calibration test will usually be found inside the cover of the box in which the meter bar is furnished.

In addition to the meter bar, quarter-meter scales, and eighth-meter scales are available. These are not tested for accuracy, and should be compared with a meter bar of known accuracy before use.

3–139 Beam compass.—The beam compass consists of a light, inflexible bar of wood or metal with a T cross-section, and two com-

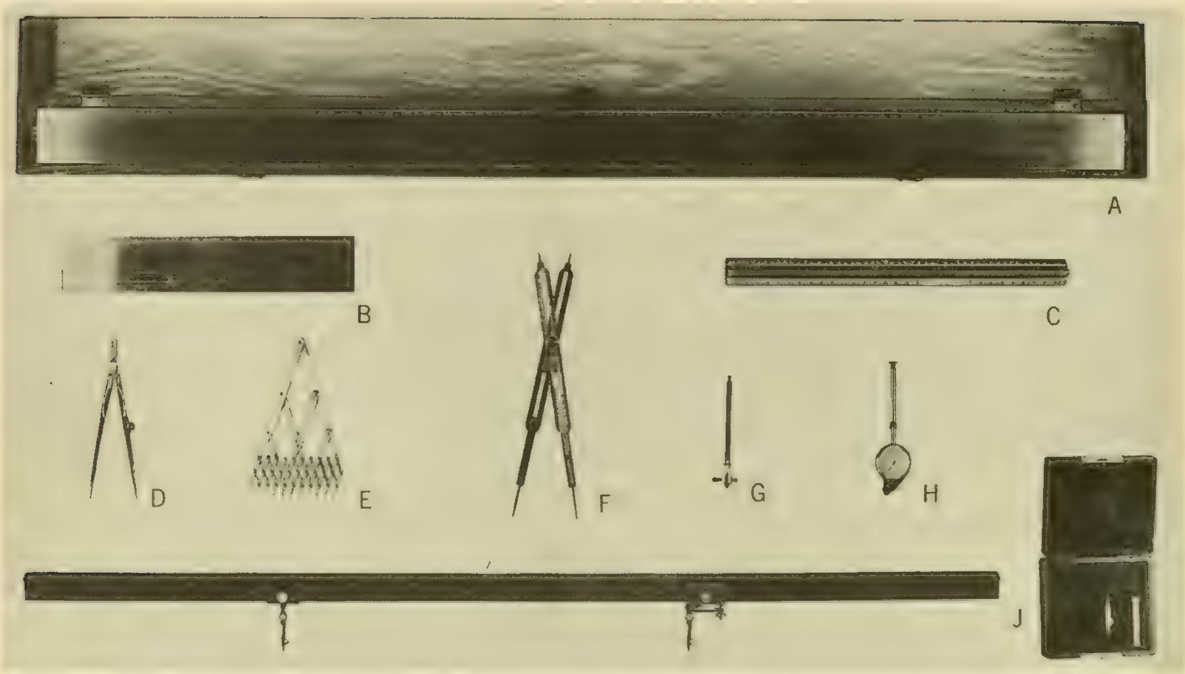


FIGURE 46.—Drafting instruments. A. Meter bar. B. One-quarter meter scale. C. Latitude and longitude scale. D. Hairspring dividers. E. Spacing dividers. F. Proportional dividers. G. Opisometer. H. Map measure. J. Beam compass.

pass fixtures which slide on the bar and can be clamped in any desired positions. It is used for measuring distances too long for ordinary dividers and to swing distance circles on hydrographic sheets. It is essential in making projections in the field. Bars are available in lengths from 24 to 60 inches, in multiples of 6 inches, and can be furnished in much greater lengths for special purposes.

When using a beam compass to draw distance circles on a smooth sheet (see 5–11), the Edmonston Beam Holder (Fig. 47) should be used when available.

3–140 Miscellaneous drafting instruments.—Various other drafting instruments will be found in the plotting room of a survey ship. Steel straight edges in lengths from 6 to 72 inches are available. Before using a straight edge in any operation requiring a truly straight line, it should be carefully tested.

To test a straight edge, two fine dots should be pricked on a thick sheet of paper at a distance apart slightly less than the length of the straight edge. With the fiducial edge centered on the dots, draw a fine line along it with a chisel-edged pencil held firmly against the edge and at a constant angle with the paper. The straight edge is then turned end for end and again centered on the pricked points. If the fiducial edge coincides with the pencil line throughout its length, it is straight, unless it happens to have a symmetrical reverse curve.

Most of the lettering on smooth sheets, planetable sheets, and sketches must be done with a mechanical lettering set. The Leroy lettering set has been adopted as the standard for most work of this kind although the Wrico sets are used in a few cases.

Curves made of heavy plastic are available for drawing distance arcs when it is impractical to draw them with a beam compass (see 5–11). The Shoran curves are furnished at a scale of 1:20,000 and with radii at one-mile intervals from 11 to 70 statute miles. EPI curves are furnished at a scale of 1:100,000 ranging from 450 to 4,100 microseconds in multiples of 50. Curves for other scales and distances can be provided if

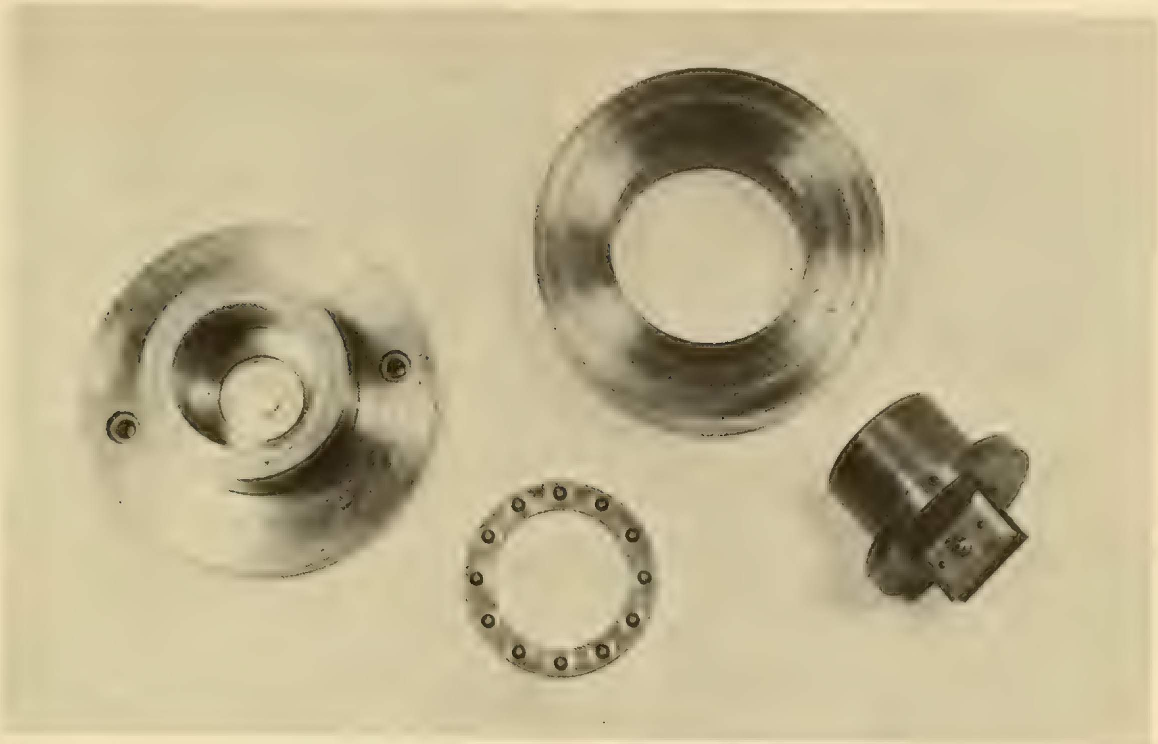


FIGURE 47.—Edmonston beam holder—disassembled.

the requirement is sufficient to justify construction of them.

3–141 Ground survey instruments.—In addition to the instruments required for hydrographic surveys, a survey party must have at hand a variety of instruments for accomplishment of all phases of the assigned combined operations project. These may include any or all of the following:

(a) Theodolites. Second order direction theodolites are used for most work. Repeating theodolites or first order direction instruments may be needed for some operations.

(b) Signal lamps for triangulation.

(c) Level and rod for leveling to tidal bench marks.

(d) Transit magnetometer for magnetic observations.

(e) Alidade, planetable, and telemeter rods for planetable traverses, topographic, or graphic control surveys.

(f) Stereoscopes for field and office work with air photographs.

(g) Base measuring equipment (tapes, stretchers, etc.) will be furnished only when needed under the terms of the project instructions.

(h) Large survey vessels should always carry wire drag gear in amounts sufficient to accomplish any necessary investigations (see 5–124).

The instruments and equipment in the foregoing list are described in other manuals which also contain detailed instructions for their use.

3–142 Tide gages.—Tide gages may be divided into two groups—non-registering gages which require the presence of an observer to record the height of the tide, and self-registering or automatic tide gages which record the rise and fall of the tide. Both types of gages are fully described in Special Publication No. 196, Manual of Tide Observations.

The Coast and Geodetic Survey uses two principal kinds of automatic tide gages which record the tide graphically. The standard

gage is designed for use at primary stations, or at stations where observations are to be continued for long periods of time (see 2–50). The portable gage requires a less elaborate installation and is used at tide stations where a comparatively short series of observations are required. Both types of gages are activated by a float as it rises or falls in a well.

Float wells may be constructed of various materials to suit the conditions of installation. The float used with a standard tide gage is 8½ inches in diameter, and the portable tide gage float is 3¼ inches in diameter. Rough lumber may be used to construct the wells at any temporary station. The heavy iron or steel pipes which have been used for many years are being replaced by lighter material such as molded fiber glass, polyvinyl chloride pipe, and various types of soil pipe. The fiber glass is particularly suitable for use at permanent installations.

A new type of pressure gage is being tested, and is called a "bubbler" gage. One end of a small tube is held at a fixed position below the surface of the water and air or gas under pressure is fed into the tube so that small amounts will escape through the submerged end at the highest tide expected. The other end of the tube is connected to a pressure measuring element which is self-compensating for atmospheric pressure and temperature. The change in pressure caused by the tide is measured and recorded graphically. A telemetering device can be used at the gage to transmit the information by radio or telephone to a distant recorder.

Complete instructions for installation and servicing of all types of gages, except the pressure gage, are contained in Special Publication No. 196. All installations shall comply with these instructions.

3–143 Tide records.—Report—Tide Station, Form 681, shall be submitted in duplicate for each tide station established or inspected. The tide staff shall be connected by spirit levels with at least three bench marks and the results of the leveling recorded in Form 258, Leveling Record—Tide Station. These reports and records shall be forwarded to the Office promptly (see 2–52).

The exact location of each tide station shall be shown on hydrographic sheets. The time meridian used shall be shown on tide records. The marigrams from portable gages shall be forwarded to Washington for each two weeks of satisfactory operation, if practicable. When a station is discontinued, it shall be noted on the original tide record. The roll on a standard tide gage shall be removed and forwarded to the Office on the first day of each calendar month or as soon thereafter as possible. Hourly heights required for reduction of soundings shall be scaled from portable gage records by the field party before the marigrams are forwarded to Washington. Hourly heights from standard gage records will be furnished by the Washington Office on request.

3–144 Current meters.—Current velocities are measured by three instruments: current pole and log line, Price current meter, and Roberts Radio Current Meter. The first two are described in Special Publication No. 215, Manual of Current Observations, and the third in the Roberts Radio Current Meter Operating Manual, 1952 Edition.

The current pole and Price meter observations are made from a vessel at anchor. The meter may be suspended at any desired depth, but provides information as to velocity only. The radio meter is suspended from a specially designed buoy which contains the radio transmitter and on which an antenna is mounted. One, two, or three meters may be suspended from the same buoy and data transmitted from each meter in turn at intervals determined by operation of a sequence switch. The meter measures the velocity and direction of the current. The data are recorded on chronograph tapes through a radio receiver aboard the survey vessel. A recorder may be installed in the buoy and the data recorded automatically on waxed tape. Special instructions are issued with the recorder.

In the past, each buoy transmitter was assigned a frequency and broadcast data continuously. With this system, it is necessary to tune in each buoy individually to

receive the data, and the frequencies used are subject to interference by static and other signals. A new system for telemetering the data has been developed using frequency modulation and a challenging signal. In this system each buoy transmits data on the same frequency, but for a limited period of time. A receiver in the buoy responds to an assigned tone signal from the ship, it turns on the transmitter, selects the top meter in a series, and transmits data from each meter in sequence from top to bottom, and then turns the transmitter off. Although a frequency of 34.96 megacycles has been permanently assigned to the Coast and Geodetic Survey, it is necessary to obtain clearance for its used on a regional basis. This frequency should not be used unless specifically authorized by the Washington Office. Though the system does not completely eliminate previous difficulties caused by various kinds of radio interference, it has substantially reduced it, and has eliminated the problems involved in tuning in the various buoy transmitters.

4. CONTROL AND SIGNAL BUILDING

4–1 **Basic control.**—All hydrographic surveys must be controlled by a system of geodetic triangulation or traverse established with an accuracy not less than that prescribed for third-order control (see 1–15). Although triangulation stations have been established in most coastal areas of the United States and the territories, a hydrographic party frequently finds it necessary to establish supplemental control or to re-establish lost stations. Second-order methods shall be used to locate all main-scheme stations, whether new or re-established. Second-order, Class II, accuracy is desired on the main-scheme triangulation, but third-order accuracy is acceptable where reoccupation of stations to obtain second-order triangle closures and side checks will be unduly expensive. Supplemental triangulation stations established solely for control of photogrammetry and hydrography, permanent fixed aids to navigation, prominent landmarks, and electronic control stations shall be located with at least third-order accuracy.

A complete discussion of and specifications for classification of horizontal control surveys is contained in the 1959 edition of Special Publication 247, Manual of Geodetic Triangulation.

All first and second order triangulation surveys, base measurements, and azimuth observations shall be accomplished in accordance with instructions contained in Special Publication 247. Third order triangulation and traverse shall comply with specifications in Special Publication 145.

4–2 **Control by traverse.**—Under certain conditions it is more expedient to establish control points by traverse methods. This is particularly true where the beach is bordered by precipitous mountain areas and in fiords surrounded by heavily wooded hills. In such cases, control can be established by Tellurometer traverses in accordance with procedures described in Publication 62–1, Tellurometer Manual, or by taped traverses as described in Special Publication 145, Manual of Second and Third Order Triangulation and Traverse. The latter method is time-consuming and expensive, and shall be used only as a last resort.

4–3 **Spacing of control.**—Triangulation or traverse stations must be frequent enough to provide basic control for the project at hand. The use of photogrammetric and electronic methods of controlling hydrographic surveys has lessened the need for a dense coverage of triangulation stations, but a certain minimum should be established and maintained for future use. The required frequency depends on the scales of the surveys, the configuration of the coastal area, and requirements to control the photogrammetric plot. Triangulation stations are used in survey work by other engineers, public and private, and the density of control should be adequate to meet anticipated needs for control in the area. In general, main scheme triangulation stations should be established at intervals of 5 to 8 miles along the coast, with supplemental third-order stations as required to provide adequate control for the project. When planetable methods are to be used to locate supplemental control points for hydrography, triangulation stations should be established at intervals of 2 to 5 miles.

4–4 **Recovery of old stations.**—The sites of all previously established control stations in the project area shall be visited, if practicable, and a thorough search made for each station and its reference marks. A report

shall be made on Form 526, Recovery Note, Triangulation Station, for each station recovered or searched for. A station should not be reported as lost unless there is conclusive evidence to establish the fact beyond a reasonable doubt. The description of the station shall be verified in detail or corrected as necessary to conform with circumstances at the time of recovery. Damaged stations or reference marks should be repaired. If it is necessary to move any of the marks at a station, the procedures described in Serial 632, The Preservation of Triangulation Station Marks, shall be used. All triangulation stations shall be marked or re-marked and the disks stamped in accordance with rules stated in Special Publication No. 247.

Where new triangulation is connected to previously established triangulation, it is necessary to verify recovery of the old stations, and to check the distances to reference marks and the angle between them to ensure that none of the station marks have been moved. This will ordinarily be considered adequate proof of recovery of a third-order station. When the connection is made to first or second-order triangulation, the two stations at the ends of the old line must be occupied and observations made to a third station of the original scheme. The measured angles should check the original observations within 3 seconds as proof of recovery.

Objects such as flagpoles, chimneys, smoke stacks, beacons, and signal towers, whose positions have been previously determined, shall not be used for control until they have been positively identified or their original positions verified.

4–5 Station marks and descriptions.—Each new station which is to be located by triangulation shall be marked with a standard bronze station-mark disk and two standard reference mark disks, except well defined natural or artificial objects located by intersection and substantially constructed objects, such as lighthouses and water tanks, where disks are unnecessary or marking impracticable. Subsurface marks shall be established at main scheme second-order stations where practicable. Azimuth marks shall be established at second- and third-order stations unless another triangulation station or at least two objects such as lighthouses, tanks, church spires, etc., are visible from the ground at the station. Instructions for naming and marking stations, and for stamping the disks are contained in Special Publication No. 247.

Each new marked triangulation station shall be described on Form 525. The description should be clear, concise, and complete. It should enable one to go with certainty to the immediate vicinity of the mark, and by the measured distances to permanent reference points it should inform the searcher of the exact location of the station. When marked stations of other organizations are included in the triangulation scheme, they should be described on Form 525.

All objects, such as spires, tanks, etc., located by intersection, shall be described on Form 525–b. An observer shall visit the station and identify the object by a descriptive name, name of owner, and year of construction. Lighthouses and other fixed aids shall be identified by name as shown in the most recent issue of the Light List.

4–6 Connections with triangulation of other organizations.—Independent schemes of triangulation, which have been established in the project area by other organizations, shall be connected to the triangulation of this Bureau by strong figures in such a way that their positions may be computed and adjusted on the datum appropriate to the area, (NA–1927 in the continental U.S. and Alaska) if this is feasible. A line connection is preferable to a point connection. Federal, State, and local agencies should be contacted to ascertain what control exists in the project area, and to obtain copies of descriptions and positions of marks and diagrams of the control schemes.

If practicable, the positions of stations established by other organizations should be determined in lieu of establishing new stations nearby, provided the station marks are in good condition and suitably located. Two standard reference marks should be established if none exist. Under no circumstances

shall survey station marks of other organizations be altered or amended by stamping. Neither shall they be moved, replaced, or reset unless the project instructions so specify. If need be, such marks should be reinforced to prolong their existence, but special precautions must be taken not to disturb or move them, either horizontally or vertically.

4–7 **Theodolite cuts.**—A triangulation station must be of third-order accuracy or higher, and any stations located by geodetic methods, which do not comply with triangulation standards, are classified as topographic stations. Among the latter are: (a) any station located by a single triangle, one angle of which is concluded; (b) an intersection station located by an insufficient number of directions to provide a check on its position; (c) a station located by theodolite by the three-point problem, without a check; (d) a temporary station which is unmarked and nonrecoverable; (e) any station located by any method or scheme, which depends in part on floating or moveable objects, such as ship-to-shore triangulation. If stations of this class are marked, a topographic station disk shall always be used, never a triangulation station disk (see 4–24). The records and computations for such stations shall be forwarded with the topographic or photogrammetric data and reports.

4–8 **Use of air photographs in reconnaissance.**—Reconnaissance for the selection of sites for control stations may be greatly facilitated by the use of air photographs. The photographs should be matched to form a temporary mosaic and studied under a stereoscope. If straight lines are drawn, preferable with white ink, between possible sites for triangulation stations on each photograph, the lines will fuse to form lines in space when the photographs are viewed under a stereoscope. It will then be immediately apparent whether the lines are clear, blocked, or grazing. Reconnaissance on the ground may then be reduced to an examination of the doubtful lines. The study of the photographs will also furnish information for the location of hydrographic signals, the best landing places, and routes to inland triangulation stations.

4–9 **Topography.**—A topographic survey is the determination of the positions, on the earth's surface, of the natural features and the culture of a locality and the delineation of them on a plane surface called a topographic map. Although the depths in the water area are the most important data on a nautical chart, the topographic features of coast line are only slightly less important because, in sight of land, the mariner is chiefly guided by, and determines his position from, the aids to navigation and the shore landmarks which he can identify. A chart should include the topographic details of the adjacent shore and all the salient features of landmark value that are visible from a ship at sea.

Virtually all topographic surveys are now being made photogrammetrically. Instructions for photogrammetric field work are contained in a series of Photogrammetric Instructions which have been promulgated over a period of several years. Office procedures are described in Special Publication No. 248, Topographic Manual, Part II, 1949 edition. Planetable methods are still used when expedient, but primarily for the location of signals (see 1–17). Complete instructions and specifications for topographic surveying by planetable methods are contained in Special Publication No. 144, Topographic Manual. Part I of the new Topographic Manual, when published, will supersede Special Publication No. 144 and the series of photogrammetric instructions. Except as modified in the project instructions and in this Manual, the requirements stated in the above publications shall be strictly followed by hydrographic parties engaged in topographic surveys.

4–10 **Photogrammetry.**—Except in Alaska and similar remote areas where water transportation is essential to successful operations, the Photogrammetry Division will accomplish all field work required to produce advance manuscripts (shoreline, planimetric, or topographic) prior to the beginning

of a hydrographic survey. When project plans permit, this work will be done one year in advance of the hydrographic survey.

In areas where control indentification and shoreline inspection must be done by a hydrographic party, the field work should be done in sufficient time to permit completion of incomplete or advance manuscripts prior to the beginning of hydrographic surveys (see 1–16). A lead time of 3 to 6 months is required, depending upon the size and complexity of the areas to be mapped.

4–11 Control identification.—Instructions for identification of horizontal control stations are contained in Photogrammetric Instruction No. 22, Revision 1. When a hydrographic party is required to identify control in advance of a photogrammetric plot, a sketch of the project area will be furnished showing the approximate sites where control points are desired. If there is an existing scheme of triangulation, the instructions may require identification of only a few selected stations. The identification of the station, or a substitute point close by, must be positive and very carefully done. There is no objection to the identification of stations in excess of requirements if such identification is equally accurate. The point must be identified within 0.15 mm. of its true location, at the scale of the photograph (see 1–16). Incorrect or poor identification of control will have the same effect on the compilation as similar inaccuracies in geographic positions or plotting of triangulation stations.

A Control Station Identification (C.S.I.) card, Form 152, shall be prepared for each horizontal control station identified to control a photogrammetric plot, regardless of the method of identification.

If the project instructions specify establishment of additional triangulation in advance of photogrammetric surveys, all new stations shall be identified on the photographs. When photographs are to be taken soon after establishment of control, a white ground mark at each station will facilitate identification.

When the substitute method is used, at least two substitute points should be identified. Small offlying rocks near stations along the coast are excellent substitute stations. If distances cannot be taped, stadia distances are satisfactory if accurate to about 1 meter.

Identification of any point shall be done after careful study of the photograph under a steroscope. A fine pointed needle shall be used to prick the point in the emulsion. Under no circumstances shall a hole be punched through the paper.

4–12 Classification of photogrammetric map manuscripts.—Photogrammetric map manuscripts are classified and labeled in accordance with Photogrammetric Instruction No. 48, dated 9-3-54, as follows:

(a) Preliminary manuscript. This manuscript has been prepared without prior field identification of control or field inspection. It will be completely recompiled after receipt of control identification and inspection data.

(b) Incomplete manuscript. This manuscript is based on field identified control and is a final photogrammetric plot, but the delineation of details is incomplete. It will be completed after additional field inspection data are received.

(c) Advance manuscript. This manuscript is based on field identified control and field inspection data. It is subject to correction if errors are found in the field or during office review.

If the manuscript is not labeled in one of the above categories, it is a final manuscript.

4–13 Use of preliminary manuscripts.—A preliminary manuscript is based on office-identified control, but in making the photogrammetric plot the photographs are rigidly held in relation to each other rather than being held to the triangulation stations. This results in a plot which is consistent within itself, but will be out of position by varying amounts as compared to the triangulation control. Photo-hydro stations located on a preliminary manuscript may be used to control hydrography, but such stations should not be used in conjunction with

triangulation stations plotted by geographic positions or photo-hydro signals located on adjacent advance or final manuscripts. See Photogrammetry Instruction 45, Revision 1, 15 March 1954.

Shoreline and offshore detail shall be transferred to the boat sheet and inked, but a preliminary manuscript shall not be used to transfer any information to a smooth sheet (see 6–26).

A preliminary manuscript must be recompiled after control has been identified. Obviously this is inefficient and Chiefs of Party should establish and identify control far enough in advance of hydrographic work to avoid the necessity of using preliminary manuscripts.

4–14 Use of incomplete manuscripts.—An incomplete manuscript is a final photogrammetric plot based on field identified control but with insufficient field inspection of topographic detail particularly along the shore. The location of photo-hydro signals on this class of manuscript is final and such signals may be transferred directly to the smooth sheet. Since the shoreline and alongshore detail or sections thereof are compiled largely from office interpretation of the photographs, it is expected that some errors will occur. These errors will be corrected in the office on the basis of the field inspection reports submitted by the hydrographic party (see 4–16 and 4–17).

4–15 Use of advance manuscripts.—No additional office work will be done on these manuscripts unless errors are found during the hydrographic surveys. The locations of photo-hydro signals on this class of manuscript are final. The shoreline and offshore detail shall be verified or corrected as specified in 4–16 and 4–17.

4–16 Shoreline inspection.—Where preliminary and incomplete manuscripts have been compiled from an office interpretation of the photographs and no errors are found in the shorline and alongshore detail during the hydrographic survey, no field inspection notes are required. Where they are incorrect, sufficient notes shall be made on the field photographs and paper prints of the manuscripts to enable the compiler to map the shoreline correctly. When changes are numerous, the manuscript will be corrected and a new blueline copy will be furnished for application of shoreline to the smooth sheet (see 6–26).

Instructions for field inspection of shoreline are contained in Photogrammetric Instruction 49 dated 18 March 1944. In Alaska the foul line symbol is frequently used to outline shoal and rocky areas in which detail is not clearly visible on the photographs. Where additional detail is required in any such area, the information shall be shown as above or on the boat sheet. In Alaska it is not intended that all shoreline be inspected in detail, but rather that short stretches of typical shoreline be field inspected at convenient and practicable landing places.

Where appreciable accretion or erosion has taken place since the date of the photographs or field inspection, the photogrammetric manuscript may be corrected by various methods. When planetable methods are being used to locate supplemental control, the shoreline shall be corrected on the graphic control sheet. In other cases the paper print of the manuscript may be used if excessive distortion is not a factor. A section of shoreline may be transferred to an aluminum-mounted sheet without projection and the new shoreline corrected. The blackline impression may also be used as a topographic sheet and corrections surveyed directly thereon. A photograph may be used in the same way, however, this method is complicated for use except by experienced photogrammetrists.

The shoreline corrections can be determined by sextant fixes when planetable methods are impracticable. As a last choice, the corrections can be made by sketching the shoreline by estimated distances from fixed positions along the shore as hydrography progresses.

Where the shoreline has been revised by standard topographic methods, or methods of equal accuracy, the revised shoreline shall

be shown on the boat sheet by a solid red line.

Where the revised shoreline has been located by less accurate methods it shall be shown by a broken red line.

4–17 Field inspection report.—All hydrographic parties which field inspect shoreline or identify control, either horizontal or vertical, on the photographs, shall submit a field inspection report in accordance with Sections 718 and 724 of Topographic Manual, Part II. A progress sketch shall be forwarded with the report showing previously established horizontal and vertical control stations which are recovered and identified, and new stations established and identified.

4–18 Location of photo-hydro stations.—Stations for control of hydrography located by photogrammetric methods, known as photo-hydro stations, shall be established in accordance with Photogrammetry Instruction 45, Revision 1, dated 15 March 1954. The identification of the photo-hydro point should be pricked on the photograph within 0.2 mm. of its true position.

Photogrammetric methods shall be used to locate supplemental stations for control of hydrography whenever practicable (see 1–16). In areas where photographs do not contain sufficient detail to permit photogrammetric positioning of signals at minimum intervals required for control, various other methods may be used to supplement the photogrammetry. In narrow inlets, bays, and passages, planetable graphic control surveys, based on triangulation control or on points located by the photogrammetric plot, will provide control of sufficient accuracy. A planetable traverse starting at a station located by the photogrammetric plot and closing at another similarly located station, may be used, but the length of the traverse should seldom exceed one mile. A stadia distance and azimuth from a known point to a signal may be used, but the distance in meters and the azimuth line should be inked on the boat sheet. Three well-intersected sextant cuts from points located by the photogrammetric plot may be used to locate a signal. The orientation station used for each cut should be as distant as possible. In all the above cases the identification of the photogrammetric points used must be positive.

Identifiable points, such as small rocks, corners of buildings or piers, and forks of streams may be used as hydrographic signals. Supplemental stations may be located by reference measurements to such detail, if the objects themselves are not convenient for use as signals or as sites for erection of signals. (Photogrammetry Instruction 22, Revision 1.)

4–19 Photogrammetric data.—A hydrographic party will usually be furnished field and office photographs, blackline impressions, paper prints, and blueline tracings of photogrammetric manuscripts.

If preliminary manuscripts are furnished, all photographs, C.S.I. cards, shoreline inspection reports, and associated data shall be forwarded to a photogrammetric office to be specified by the Washington Office. The data should be forwarded as rapidly as field work is completed on one or two manuscripts and should not be retained until the end of the season. Office processing will be scheduled to provide blueline tracings of advance manuscripts as needed for smooth plotting hydrographic surveys.

If significant changes are found on incomplete or advance manuscripts, all photographs and field inspection reports should be forwarded to the Washington Office. New blueline tracings will be furnished after the manuscript has been corrected.

If office revision of the map manuscripts is not required, the photographs shall be returned to the Washington Office, and all other photogrammetric data shall be submitted with the hydrographic records.

4–20 Planetable surveys.—The hydrographic party will rarely find it necessary to make a topographic survey by planetable methods. However, it may be expedient to locate signals for control of hydrography by planetable graphic control surveys.

When a hydrographic survey is required at a scale larger than that of the photogram-

metry, a planetable shall be used to locate the supplemental control. In such cases the photographs should be examined to ascertain whether all topographic detail can be compiled at the enlarged scale. Such features as piling, small buildings and details around piers and slips shall be located by the planetable survey if they are not clear in the photographs.

When the high water line is obscured by overhanging trees or by shadows and there are an insufficient number of identifiable points to permit photogrammetric location of all signals, planetable graphic control methods should be used. Triangulation stations, if available, shall be used to control the survey. In the absence of triangulation, photo-points may be transferred from the manuscript and used to control the graphic survey, provided that all such points can be accurately identified on the ground.

4–21 Accuracy of topographic signal locations.—An aluminum-mounted sheet 24 by 31 inches, which is identical with the size of the planetable board, shall be used for graphic control surveys and for planetable topographic surveys. The methods and instruments used shall be such that 90 percent of the control stations located shall be within 0.5 mm. of correct geographic position at the scale of the sheet, and no station shall be in error more than 0.8 mm. Closing errors of planetable traverses, prior to adjustment, shall not exceed 0.4 mm. per mile at the scale of the sheet, and in no case shall the total closing error which may be adjusted exceed 2.0 mm. at the scale of the sheet (see 1–17).

4–22 Shoreline by planetable.—When planetable methods are used to locate minor control stations, the highwater line should be located by at least three rod readings near each planetable setup. Each rod reading should be indicated by a black dot and the highwater line drawn in black between the readings leaving a short hiatus on each side of the dot. The high-water line at a rocky point which is difficult to interpret in the photographs should be located by planetable when time permits.

4–23 Planetable sheet numbers and reports.—Each planetable sheet shall be designated by a capital letter assigned in alphabetical order during the season. A new series starting with "A" shall be used each season. The complete designation shall be composed of the first two letters of the name of the survey vessel, or other assigned designator, followed by the capital letter, followed by the last two digits of the year, all connected by hyphens. For example SU–C–59 would indicate the third topographic sheet initiated by the Ship SURVEYOR in 1959. The location of each sheet shall be shown on the sheet layout sketch for the project.

If the survey contains important shoreline information, a registry number will be assigned on request to the Washington Office. If the survey contains only minor shoreline details or corrections, or if it is a graphic control survey for location of signals only, the data will be transferred to the smooth hydrographic sheet and no registry number will be assigned. Such sheets will be destroyed after the smooth sheet has been verified, inked, and reviewed.

A descriptive report shall be written to accompany each topographic sheet as specified on pages 11 and 12 of the Topographic Manual.

4–24 Marked topographic stations.—To provide for future use in revision surveys, the topographer or photogrammetrist shall supplement existing control by establishing additional recoverable stations at intervals which will vary with the nature of the area. In areas where revision surveys will be required because of natural or artificial changes, stations should be established at intervals of one mile along the coast. In isolated areas, along difficult coastlines, and where changes are not expected, recoverable stations shall be established at not less than 2-mile intervals.

These recoverable stations may be natural or artificial objects when available, or standard topographic station disks set especially for this purpose. Stations should be established where they can be easily identified and in the most prominent places, such as

conspicuous points, rock outcrops, and large boulders.

All topographic stations specially marked for future recovery shall be marked with a standard bronze topographic station disk stamped with the name and year of establishment. Reference marks are not set at topographic stations. The stations may be located by planetable or photogrammetric methods (see 4–7).

4–25 Description of recoverable topographic stations.—New recoverable topographic stations shall be described on Form 524. If the station is located by photogrammetric methods a C.S.I. card, Form 152, or 153, shall be submitted also. Form 524 should contain a full description of the station just as for a triangulation station (see 4–5). If there are suitable reference points in the vicinity, the distances and directions to them should be shown in a sketch.

The same form shall be used to report the recovery of a topographic station. A conspicuous capital R should be printed in the upper right-hand corner of the card. If the original description is correct and adequate a statement to this effect is sufficient. If it is inadequate a complete new description should be written. If the station is not recovered, state whether it should be considered lost, giving particulars, and the time spent in searching for the station.

4–26 Sextant angle location of signals.—Occasionally it is necessary to locate a signal by sextant angles to supplement the established control. The station may be located by observing a strong three-point fix at the station (see 1–18). A check angle to a fourth station should always be measured. A navigating sextant should be used and wherever practicable the angles should be observed to triangulation stations. The position on the boat and smooth sheets may be plotted with a three-armed metal protractor or the position may be computed.

The station may be located by fixing the position of the survey vessel by strong three-point sextant fixes and simultaneously observing a cut to the station. At least three well-intersected cuts are required. The vessel should be stationary when the cuts are observed. Accurate results cannot be obtained from a vessel underway.

A third method which may be used is to occupy three or more control stations with a sextant, observing at each an angle from another control point to the new station. The stations should be selected to provide strong intersections of the cuts.

Stations located by sextant angles shall not be used for the purpose of locating other stations except as a last resort.

4–27 Unconventional methods of signal location.—Waterways with sufficient depth of water, or important enough to be useful in navigation, require accurate, detailed surveys, and the control in them must be established by conventional methods. In sloughs through swamp or mangrove or in minor tributaries, where the depth of water is trivial, less accurate methods can be tolerated. The control may be established by sextant triangulation. A traverse may be run using sextant angles to carry the azimuth and distances may be measured by stadia or by sextant angle using a sextometer rod. The hydrographer, by exercise of some ingenuity, can devise methods appropriate to the instruments available, such as subtense bars, range finders, or floating calibrated wire. Sextant angles should always be measured with a navigating sextant. The traverse or graphic triangulation should be plotted on an aluminum-mounted sheet, preferably at a scale twice as large as that of the hydrographic sheet. Such traverses should seldom be more than a mile in length and the end of the traverse should be firmly positioned by connection to established control of a higher order if possible without undue expense.

4–28 Hydrographic signal building.—Signals appropriately located and erected are a very important prelude to successful launch hydrography. The ease and smoothness with which a launch unit operates depend to a large extent on the competency with which the signal building party does its work.

Where the stations are located and spaced so that strong fixes will be available at any point in the area and are varied in size, shape, or color so as to be quickly and unmistakably identified, then the control will be adequate for hydrographic surveying.

Stations along a sandy beach or low flat area should be placed well back from the beach to provide strong sextant fixes with fewer signals. In any case they should be at least far enough from the beach so that they will not be destroyed by wave action during storms (see 5–40).

Where signals are built along an irregular coast, one should always be located at the head of each inlet or small cove. Stations high above the water on cliffs or bluffs are unsatisfactory for fixes close inshore. Signals need not be established with more permanency than is required to remain intact until the hydrographic survey is completed.

Care must be taken to vary the size, shape, elevation, and color of the signals to prevent confusion. The largest and most conspicuous signals should be placed at locations where they can best be seen in the offshore areas and at points which will provide strong fixes. Smaller signals should be appropriately spaced for inshore work. If the signals can be built well back from the shoreline, a spacing of approximately one every half-mile may be sufficient. Where the beach is irregular and signals must be built close to the shoreline, a spacing of 300 to 400 meters will be adequate.

4–29 Natural and artificial objects.—The term "signal" is used to designate any sort of object, natural or artificial, for use in measuring sextant angles to locate positions of a survey unit while engaged in sounding. It may be of any size or shape. It is obvious that the measurement of angles will be facilitated when the objects at the control stations are conspicuous enough to be seen readily by the observers. For this reason, as well as for economy and durability, natural objects such as lone boulders, pinnacle rocks, waterfalls, and lone trees, and artificial objects such as beacons, lighthouses, tanks, spires, and building gables, should be used as signals wherever available.

4–30 Signal building materials.—Where natural objects are not available, the most satisfactory and economic types of signals are those made of whitewash or white cloth. Whitewash properly brushed on solid rock will make the most durable signal. Such signals can usually be made in sizes appropriate to the distance at which they will be used. The nature of the project and availability of electronic equipment for offshore hydrography are the determining factors which influence distribution of large signals. There should be enough large signals to provide control for calibration of Shoran at maximum distances. For the inshore launch work small whitewashes or signals constructed of white, red, or orange cloth in various shapes such as cross banners, flags on stumps, or wrapped on trees or poles are adequate. Black cloth should be used if the signal shows against the skyline. Any signal made of cloth, except black, will show best when it reflects sunlight and will provide the best reflection if it is set at an angle of about 60 degrees. Red or orange cloth can be seen for relatively short distances, but provide a break in a series of white signals which reduces possibilities of confusion.

When cloth is used to construct a signal it should be securely fastened with a stapling gun or tacks and several 4 to 6-inch slits cut to relieve wind pressure and discourage vandalism.

Whitewash is made of pulverized, unslaked lime. The lime deteriorates rapidly and, when a stock must be kept on hand over a considerable period of time, it should be stored in water-tight metal containers. The whitewash is prepared by filling a bucket about one-quarter full of lime and adding about one gallon of water. The mixture should be stirred rapidly and a little water added as necessary to keep it from boiling over. A stick about 3 to 4 feet long should be held at arms-length to stir the mixture as it may spout up while boiling. The exploding bubbles may cause injury to the eyes and the mixer should be careful to avoid such

an accident or wear goggles while mixing the whitewash.

4–31 Entrance on private property.—Where stations and signals are to be established on private property in populated areas, permission must be obtained from the owner, and no damage or defacement of property shall be made without his consent.

Where surveys are made along the shores of publicly-owned areas, such as parks, national or state forests, or reservations, the superintendent or other official should be contacted. This is particularly important if any clearing is required.

Nothing arouses the ire of a property owner so much as unauthorized entrance on his property. When the nature of the work is explained, there will seldom be any difficulty in obtaining permission to establish a station. If it is necessary to damage crops, shrubs, or trees, the regulations must be closely followed in securing beforehand a written agreement which shall state the amount of damages to be paid. When the survey has been completed, signals shall be removed from private property or the owner shall be notified that the signals are no longer needed.

4–32 Buoy signals.—Before electronic equipment was adapted to control of hydrographic surveys, various types of buoys were used extensively for control of offshore hydrography. Detailed instructions for construction of these buoys can be obtained from the Washington Office. Floating signals of this type may occasionally be required to control surveys or investigations of small extent. The single-barrel buoy, or a smaller counterpart of it, described in 4–33 will be adequate for this purpose.

The essential parts of a survey buoy are a water-tight drum or barrel for buoyancy to support a target which is held in an upright position by a counterweight, and suitable ground tackle for anchoring. A 5-gallon gasoline or oil can painted yellow or white and anchored by a light line attached to a grapnel, makes an excellent marker buoy for a launch hydrographic party. If added visibility is required, a light bamboo pole may be secured to the can with a flag at one end and a small counterweight at the other.

4–33 One-barrel buoy.—The one-barrel buoy, illustrated in Figure 48, consists of a 55-gallon oil or gasoline barrel secured in a frame of 2- by 4-inch lumber, cross-braced with 1- by 4-inch lumber. Two cross braces are grooved to fit over the chimes of the barrel at top and bottom, and the barrel is securely held in the frame by half-inch bolts

List of Materials for One-Barrel Buoy

Description	*Size*	*Amount Required*
Lumber	2″ by 4″ by 16′	5 pieces.
Do	2″ by 4″ by 10′	1 each.
Do	1″ by 4″ by 16′	4 pieces.
Barrel, G.I.	55 gallon	1 each.
Car coupler (scrap)	180 to 200 pounds	1 each.
Eyebolt with shoulder and nut, G.I.	¾″ by 5″	1 each.
Bolts	½″ by 7″	3 each.
Rods, tie, threaded on both ends	½″ by 32″	2 each.
Nuts, hexagonal	½″	7 each.
Washers	1¼″ by 3/16″ (9/16″ hole)	7 each.
Washers	2¼″ by 3/16″ (13/16″ hole)	2 each.
Washer plates, iron	3″ by 10″ by ¼″ drilled	2 each.
Counterweight plate, iron	3″ by 15″ by ½″ drilled	1 each.
Shackle, G.I.	¾″	1 each.
Screen, wire, black	Medium mesh, 1 yard wide	2 yards.
Cloth, muslin, various colors	1 yard wide	2 yards.
Rope, Manila	3″	15 feet.
Nails	12 d. and 20 d.	
Tacks	Carpet	
Standard enameled buoy plate or muslin signal notice.		1 each.

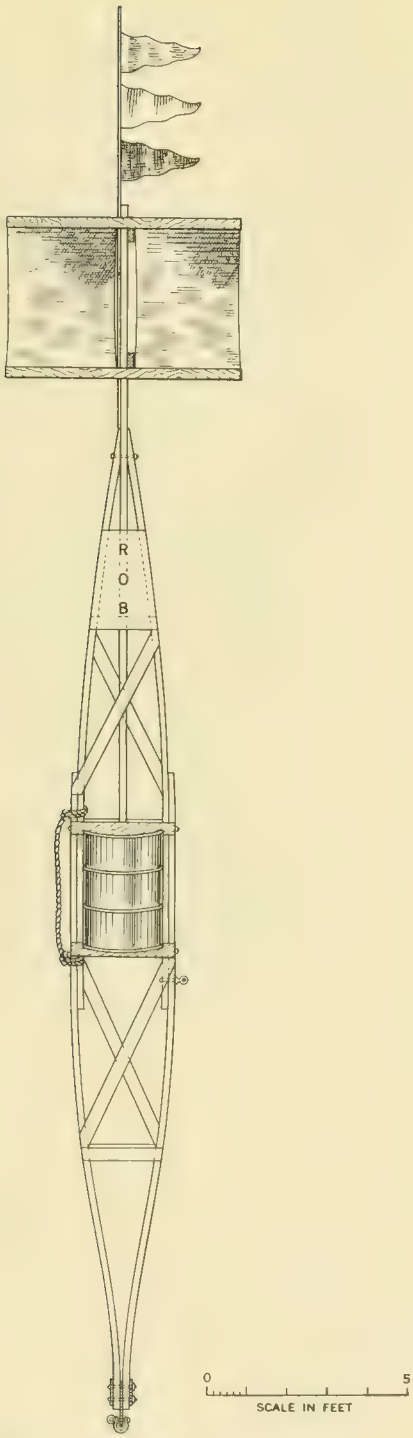


FIGURE 48.—One-barrel survey buoy.

at the top and bottom as shown in the figure.

The lower end of the buoy is fitted with suitable fixtures to which the counterweight is attached. An iron washer plate is placed on each side of the vertical frame and an iron counterweight plate between the frame members, all of which are held together by two half-inch through bolts. Three holes are drilled in the counterweight plate to take the half-inch bolts and a three-quarter inch shackle which is used to attach the counterweight to the buoy. Any iron mass or cast concrete shape of small bulk and weighing 180 to 200 pounds may be used as a counterweight.

A mast, at the top of which are nailed cross banners three feet square, is incorporated in the superstructure of the buoy, surmounted by a flatstaff on which flutter flags are tacked. The mast is nailed to the cross braces at the top of the barrel and through bolted by a half-inch bolt at the top of the frame.

A three-quarter inch eyebolt is bolted to one of the vertical frames at a position about one foot below the bottom of the barrel, and to which the anchor cable is attached. A rope sling is fitted to the opposite side of the buoy from the eye-bolt, by which it is lowered or raised. The sling is made of 3-inch Manila secured to the frame above and below the barrel.

4–34 **Small buoy.**—The buoy described in 4–33 has an over-all length of about 35 feet. Obviously it is not suitable for use on small vessels which lack deck space and adequate handling gear. For use on small vessels a miniature of the one-barrel buoy may be constructed using a 10- or 20-gallon barrel and other parts made correspondingly light for ease in handling. The buoy frame should be about 16 feet long, the counterweight should not exceed 35 pounds in weight, and a flag staff 10 feet in length may be used.

4–35 **Buoy anchoring gear.**—The ground tackle used should be appropriate to the size of the buoy, depth of water, and character of the bottom. Small Danforth anchors are

most suitable in good holding ground. When anchored in 15 fathoms or less, 3/8-inch boat chain with a scope of approximately 3 to 1 and a 30-pound Danforth anchor will be adequate for the standard buoy. In depths of 15 to 50 fathoms the cable should be composed of 3/8-inch chain and 3/8-inch wire rope with a total length equal to approximately twice the depth. The length of the wire rope should be a few fathoms less than the depth of the water. A 5/8-inch swivel should be used at each end of the wire rope to prevent snarls and kinks in the wire. Other connections should be made with screw-pin shackles and the pins secured by seizing wire.

4–36 Position of a buoy.—It is customary to lower the buoy to the water and back away from it as the anchor cable is paid out. The anchor is then released from a position over the side by a releasing hook or small line. The position of the buoy is determined at the instant the anchor is dropped. If sextant angles are used, a check angle or sum angle should be observed and the fix should be observed at the anchor. If the position is observed eccentrically, appropriate corrections shall be applied to reduce the observed position to the position of the anchor.

4–37 Control station names.—A triangulation station is generally named for the locality or for the topographic feature on which it is established. The name of the property owner is often used. In either case, the spelling of the name must be correct.

It is good practice to assign names of five or more letters to triangulation and traverse stations. One or two syllables of a long name may be used when the station is used in a three-point fix. Marked or recoverable topographic stations should be assigned four-letter names, and all supplemental stations should be assigned three-letter names.

To avoid confusion in the records, names should be selected which can be pronounced and spelled only one way. For example, AID and TOE should not be used because they are pronounced the same as ADE and TOW. Names which may be confused with numbers, such as TOO and FOR, should be avoided.

In the assignment and use of such names, the following general principles should be observed:

(a) All references to a station shall be by the name assigned to it.

(b) The same name shall be used for a station during its existence or as long as it is used.

(c) Different names shall not be assigned to the same station even in different surveys.

(d) Recovered stations used in a survey shall always retain the original names assigned to them.

(e) A duplication of names must be avoided in the same locality and shall never occur within the limits of the same hydrographic sheet.

(f) Station names shall be assigned in alphabetical order across the sheet from a list of acceptable names compiled for this purpose, such as the list of station names shown in Table 6.

4–38 Shore station shelters.—When an electronic system is to be used to control the survey and shelters for instruments and housing for personnel are not available at the selected station, temporary structures must be built. The amount of construction required varies with the equipment used and the nature of the installation. At temporary shoran stations established for launch hydrography in a limited area, the equipment may be housed in a prefabricated portable shelter about six feet square (Figure 49). The several parts of the shelter can be assembled and bolted together at the site and the unit be placed in operation in a few hours. In such cases, the electronics technician is at the station during periods of operation only.

Raydist shore station equipment is furnished in weather proof containers and may be used without a shelter. If the station is to be used for more than a few days, it is advisable to provide some type of shelter in order that servicing or repair may be accomplished during periods of inclement weather. The portable shelter described above is suitable for this purpose.

TABLE 6.—Three-letter station names

Abe	Cab	Ego	Gem	Jap	Man	Oil	Rip	Tub
Ace	Cam	Elf	Geo	Jar	Mar	Old	Rot	
Act	Car	Elm	Get	Jay	Maw	Ora	Roy	Use
Add	Cat	Emo	Gig	Jaw	Max	Orb	Rub	
Ado	Caw	End	Gin	Jib	Met	Out	Rue	Val
Ago	Cod	Eon	Gob	Jim	Mid	Owl	Rum	Van
Aha	Con	Era	Got	Job	Moo			Vet
Aim	Coo	Erg	Gum	Joe	Mop	Pad	Sad	Vex
Alp	Cop	Est	Gus	Joy	Mug	Pal	Sag	Via
Amp	Cow	Eva	Guy	Jug	Mum	Par	Sal	Vim
Amy	Cry			Jut		Paw	Sam	
Ann	Cue	Far	Hag		Nat	Peg	Sax	Wad
Ant	Cur	Fat	Hat	Ked	Nay	Pep	Set	Wag
Apt	Cut	Fed	Hem	Ken	Ned	Pet	Sic	Wan
Arm		Few	Her	Key	Neo	Pie	Sip	War
Art	Daw	Fez	Hex	Kid	New	Pin	Sir	Was
Ask	Day	Fig	Hid	Kim	Nig	Pit	Sis	Wax
Ave	Deb	Fin	His		Nil	Pix	She	Wed
Axe	Dif	Fit	Hod	Lad	Nip	Ply	Ski	Wee
Azo	Dim	Fix	Hoe	Lam	Nit	Poi	Sky	Wen
	Dip	Fly	Hon	Lax	Nix	Pot	Sly	Who
Bag	Dix	Foe	Hop	Lay	Nod	Pro	Sol	Why
Bah	Doc	Fog	How	Leg	Non	Pug	Sop	Wig
Bat	Dog	Fop	Hub	Leo	Nor	Pup	Sow	Win
Bed	Don	For	Hug	Let	Now	Put	Sox	Wit
Bib	Dot	Fox	Hum	Lip	Nub		Sty	Woo
Big	Dud	Fro	Hut	Liz	Nul	Quo	Sub	
Boa	Dun	Fry		Log	Nut		Sue	Yak
Bob	Duo	Fun	Ice	Lop	Nux	Rag		Yam
Bon			Ida	Low		Ram	Tan	Yea
Box	Ear	Gad	Ion	Lug	Oak	Rat	Tap	Yes
Bum	Eat	Gag	Irk	Lux	Obi	Rev	Tax	Yet
Bus	Ebb	Gal	Its		Odd	Rig	Thy	
But	Eel	Gam	Ivy	Mag	Off	Rim	Tom	Zag
	Egg	Gas		Mal	Ohm	Rio	Toy	Zig
							Try	Zoo

When installations of a more permanent nature are required, instrument and living shelters can be constructed as shown in Chapter 5, EPI Manual. Sheets of plywood 4 feet wide are used for siding and the structures can be built most economically in lengths and widths which are multiples of 4. If the station is to be operated on a 24-hour basis, it is best to construct separate units to house instruments and personnel.

A tent may be used to shelter electronic equipment for a few days in climates appropriate to such use. Condensation of moisture in shelters of this kind may cause rapid deterioration of the equipment and the use of tents is not recommended except in emergencies.

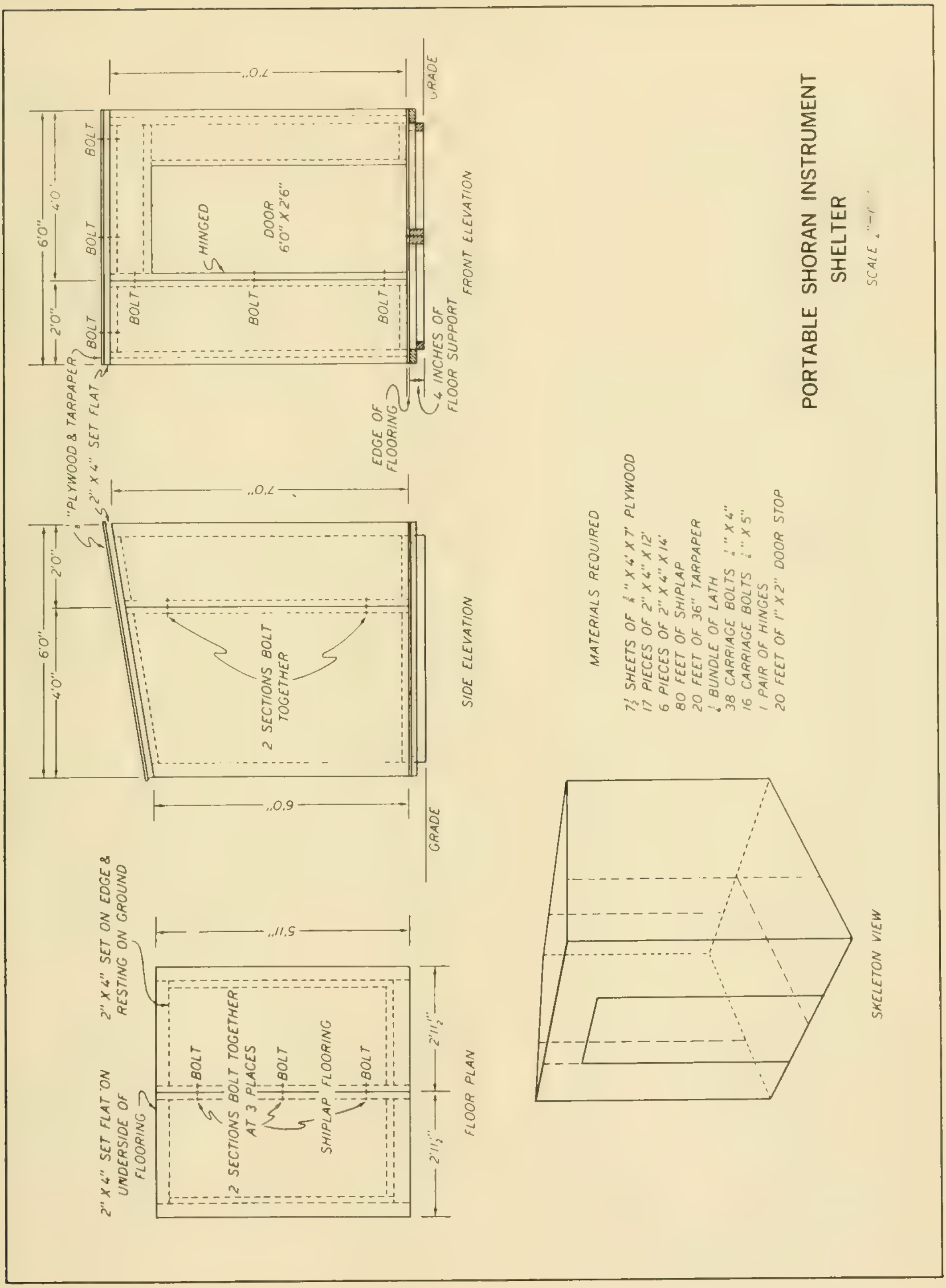


FIGURE 49.—Details of portable shelter.

5. HYDROGRAPHY

5–1 Hydrographic survey defined.—Hydrographic surveys by the Coast and Geodetic Survey are accomplished almost exclusively for the purpose of publishing nautical charts and related aids to mariners. A hydrographic survey is not complete until it meets all of the following requirements:

(a) The area has been systematically covered with accurately located depth measurements sufficient to insure that all dangers to navigation have been found (see 5–19).

(b) All underwater features have been developed including channels, shoals, banks, and reefs, and the least depth determined on all dangers to navigation.

(c) The positions of all fixed and floating aids to navigation have been accurately determined.

(d) Contemporary tide observations have been made from which soundings may be reduced to a plane of reference.

(e) Bottom samples have been obtained with sufficient frequency to reveal the general characteristics of the submerged land.

(f) Other miscellaneous operations have been completed, such as locating and describing landmarks to be charted, accumulation of data to be published in the Coast Pilots, and measurements of magnetic variations.

Sounding is perhaps the most important part of the hydrographer's duties. An accurate knowledge of the depths is essential to safe navigation, particularly in harbors and their approaches were the draft of many vessels is often nearly as great as the depths in which they navigate. It is obviously impossible to measure the depth at every point, although graphically recorded echo soundings do provide a continuous profile along each line. A hydrographic survey is considered complete when enough profiles have been obtained to determine bottom slopes in all areas. The possibility of undiscovered irregularities, and even dangers to navigation, existing between sounding lines is always present. The greatest responsibility of the hydrographer is to make sure that none remains undetected and that, when found, their least depths are determined.

5–2 Classification of surveys.—Hydrographic surveys may be classified as basic, revision, special, or reconnaissance. The project instructions will specify which is required (see 2–4 and 2–8). A basic survey must be so complete that it does not need to be supplemented by other surveys, and it must be adequate to supersede for charting purposes all prior surveys and satisfy all requirements set forth in 5–1. In addition it must verify or disprove the existence of charted or reported features.

A basic survey need not cover channels and other areas recently surveyed adequately on an acceptable scale by other qualified organizations such as the United States Corps of Engineers, provided that the survey can be correlated with the basic survey and a satisfactory agreement of depths is attained at the junction of the surveys (see 5–16).

A special survey usually covers a small area and is made for a specific purpose, such as to prove or disprove the existence of reported dangers or obstructions, to provide data for harbor development, or to supplement prior surveys for construction of a large scale chart (see 5–126). Such a survey shall comply with the specifications for a basic survey with respect to sounding operations.

Many leadline surveys made before the

development of echo sounding equipment are considered inadequate for modern charting purposes. Some areas are subject to change by storms, tidal currents, or engineering developments and must be resurveyed periodically. These are revision surveys and instructions may require a complete basic survey of the area, or limited surveys in areas of danger (see 5–125 and 127).

5–3 Survey operations.—Instructions for a survey project (see 2–5 to 13) will be issued and the necessary data furnished sufficiently in advance of field work to permit formulation of a general plan of operation (see 2–15). Plans for day to day operations must be fitted into the general plan as circumstances dictate in order that operations can be carried on smoothly and efficiently. All survey operations required in an area should be completed as the work progresses. Miscellaneous operations such as magnetic observations, development of shoal indications, compilation of coast Pilot notes, etc., should be kept up to date.

A hydrographic survey has not served its ultimate purpose until it has been incorporated in a published nautical chart. The data accumulated should be processed as rapidly as possible. Periods of inclement weather should be devoted to processing, and, when a considerable volume of unprocessed records have been accumulated, it is advisable to use periods of marginal weather for this purpose (see 5–100 to 123 and Chapter 6).

5–4 The boat sheet.—The boat sheet is the hydrographer's work sheet used in the field to plot the details of a survey while it is in progress. On it is laid out a proposed plan of sounding lines spaced in accordance with instructions. Fixed position are plotted as they are observed. Soundings, reduced for tide or other significant corrections, are inked on the sheet and depth curves drawn. Daily examination of the results will disclose indications of shoals which must be examined and where additional lines are required to comply with project instructions or to define depth curves more adequately.

The boat sheet is similar to the smooth sheet (see Chapter 6) but may be less accurate and generally not so neatly done, but all information plotted on it should be as accurate as circumstances permit and clearly legible. No important information should be omitted. Temporary or permanent notes may be written in margins or on land areas.

A photographic copy of the boat sheet will be used to apply corrections, if necessary, to the chart of the area. The boat sheet will be used by the smooth plotter and will be referred to many times as the smooth sheet is verified and reviewed.

5–5 Boat-smooth sheet.—When surveys are being made in offshore areas and electronic control is used, the boat-smooth sheet method of plotting the hydrography can be used to advantage, especially where very little development is required. When this method is used, the instructions for smooth plotting contained in Chapter 6 shall be followed with one exception: corrections to observed distances to the fixed stations shall be determined by careful calibration as described in Chapter 3, and the corrections applied on the abstract sheets as the positions are plotted. The records or descriptive report shall indicate any plottable differences between the final corrections and those used to plot the hydrography.

A transparent cover with matching projection ticks shall be placed over the smooth sheet while positions are being plotted. Tracing cloth or a thin sheet of grained mylar may be used for this purpose. As the positions are plotted they shall be pricked through the cover sheet to the smooth sheet. The cover sheet shall serve as a boat sheet and all position numbers and soundings shall be inked on it in the usual manner. At the end of the day or at other convenient times, the cover sheet is lifted and the positions on the smooth sheet connected by fine pencil lines. The position numbers are carefully inked in accordance with smooth sheet practices (see 1–10 and 6–45).

After all corrections have been applied the reduced soundings are plotted on the smooth sheet in pencil. Ordinarily the soundings are

not pencilled until the survey is complete, since movement of the cover sheet can produce undesirable graphite smears on the smooth sheet.

The boat-smooth sheet method of plotting a survey affords a real saving since only one projection is required and it is not necessary to plot positions a second time. The method is not restricted to use with electronic control systems. Chiefs of party should use this method of plotting whenever it is practicable.

5–6 Construction of boat sheet.—Boat sheets are constructed to cover specific areas as shown on the approved sheet layout (see 2–20). Boat sheet paper will be furnished by the Washington Office in flat sheets 36 by 60 inches or 42 by 60 inches (see 1–9). Boat sheet paper mounted on thin aluminum foil 36 inches wide is also available in rolls. Because of its greater stability, the aluminum-mounted paper is most suitable for use when distance arcs must be drawn during progress of a survey. Since this kind of paper will crack when bent sharply, its use is not authorized for smooth sheets or boat-smooth sheets.

The projections are constructed in accordance with instructions contained in Special Publication No. 5 (see 1–12). A layout sketch of the projection with distances in meters appropriate to the scale noted thereon should be made and checked before the projection is constructed. The layout may be retained for later use in constructing the smooth sheet projection. Although a boat sheet is subject to considerable distortion by rough use and exposure during progress of a survey, the projection should be accurately constructed and verified. See Table 1 for projection line intervals.

The projection should be constructed and checked the same day. The dms. and dps. of control stations should be plotted and checked as soon as possible. When electronic control is to be used, the distance circles should be drawn if the station locations are known (see 5–11). The projection is then inked in fine full lines about 0.15 mm wide.

Stamp No. 42, Hydrographic Survey (Fig. 50), shall be impressed in the lower right-hand corner and entries made in all applicable spaces. The initials of the persons plotting and verifying each item should be entered, together with the dates.

5–7 Projection template.—A template on Mylar, a very stable plastic, has been devised to facilitate construction of boat and smooth sheet projections. Nine points are marked on the template so that construction lines may be quickly and easily drawn. The construction procedure is as follows:

(a) Locate the center of the projection on the sheet. This is the intersection of the central meridian and parallel.

(b) Place the template on the sheet with the central point over the center of the projection and orient the template as required by the layout.

(c) Prick all nine points on the sheet and check the long diagonals to prove the perpendicularity of the construction lines.

(d) Draw pencil lines through the points in a north-south direction. The center line is the central meridian.

(e) Draw the central parallel construction line through the three points in the east-west direction.

(f) From line (e) set off the distances on lines (d) to the most northerly and southerly parallels and draw them.

(g) From the central meridian set off on lines (e) and (f) the extreme east and west meridians and draw them.

After the curvature values have been ap-

No. 42 HYDROGRAPHIC SURVEY

Field No. EX 10-3-59 Reg. No H8643

Scale 1: 10,000 Plotted: Verified

Projection: H.L.P R.C.B

Tri Sta: H.L.P R.C.B

Topo Sta: H.L.P R.C.B

Hydro. Sta: H.L.P R.C.B

Datum North American 1927

Ref. Sta. SHARP 1953

Lat 51 43 1334.9 m Adj

Long 176 20 927.8 m ~~Adj~~

FIGURE 50.—Facsimile of Stamp No. 42, projection and control data.

plied the four corners of the projection are located and the principle lines may be subdivided to draw the rest of the projection. Curvature values shall be included where necessary according to the scale of the projection.

5–8 Duplicate boat sheets.—When more than one survey unit is to work in the area covered by one boat sheet, a duplicate boat sheet can be made by pricking through the projection intersections with a fine needle. A long steel straight edge should be placed along each line as the points are pricked, being careful not to disturb the relation between the two sheets as the straight edge is moved.

Field numbers are assigned as in 1–13. The letter A should be added to the number on the original sheet and duplicates indicated by adding letters B, C, etc., to the field numbers.

When the area to be surveyed lies entirely within the limits of a photogrammetric manuscript, a boat sheet may be made by transferring the projection and shoreline from the blueline tracing of the manuscript. Joining two or more manuscripts for this purpose shall not be attempted.

5–9 Calibration sheets.—If a projection is required for calibration of an electronic control system it shall be constructed on an aluminum-mounted sheet of appropriate size. It is desirable that the scale of the projection be twice as large as the largest scale survey on which the system is to be used, and it must never be smaller than the largest scale survey sheet. The method of construction and plotting control are the same as for other projections, but the work must be very accurately done. The sheets are not numbered. They may be discarded after all data have been tabulated and verified.

5–10 Control stations.—All control stations, whose positions are known at the start of the survey, should be plotted on or transferred to the boat sheet and shall be shown by standard symbols (Fig. 79). The names of stations may be lettered on the boat sheet in freehand, provided they are unmistakably legible. They should not be placed in water areas or obliterate any essential detail on the boat sheet and must be placed so that they are clearly associated with the correct symbols (see 6–15). Existing names of control stations must be retained with their exact spelling. If a station is in the water area, such as a beacon or offlying rock, the name may be inked on land area nearby and an arrow or leader used to indicate the station to which the name refers. For each control station in the water area, notation should be made on the boat sheet as to whether the feature on which it is erected is permanent or temporary, and a short description should be added.

When control stations are numerous, as on an inshore hydrographic sheet, identification will be aided and confusion avoided if brief descriptions of the signals are noted on the boat sheet.

Each natural object used as a control station shall be described on the boat sheet. When it is conspicuous enough for use as a landmark, that fact should be included in the description.

As new control stations are located, they shall be plotted on the boat sheet by direct transfer or other accurate method. The plotting of all control stations should be verified before the station symbols are inked, and the fact noted on the boat sheet.

5–11 Electronic distance circles.—When an electronic system is to be used for the control of hydrography and the locations of the shore stations are known, arcs of distance circles should be drawn as soon as the projection has been verified. If the arcs must be drawn at a later date as the survey progresses, the projection should be checked for distortion and significant amounts equally distributed by procedures described in the following paragraphs.

When the shore stations fall on the sheet, the arcs can be drawn directly with a beam compass. Colored inks shall be used with a distinctive color assigned to each station. A circle of the same color about 5 mm in diameter, shall be drawn around the station

symbol. If an Edmonston Beam Holder is not available, a Horn center should be placed over the station mark to prevent damage to the sheet as the arcs are drawn. Radii for the circles should be measured along three lines drawn from the station. When boat-smooth sheet procedures are to be used, it is best to compute three points on the circle of largest radius and plot these points on the projection. If the measured distance does not check the plotted points the radius of each arc shall be multiplied by a factor which will distribute the distortion uniformly across the sheet.

The station may be off the limits of the sheet, in which case it is necessary to compute at least three points on three or four circles. When the area to be surveyed is not too far distant from the station, the outline of the boat sheet limits can be plotted on a nautical chart and three or four radial lines drawn from the station across the sheet as shown in Figure 51. The azimuth of the lines may be measured with a protractor and the distances scaled off the chart. Because of the distortion inherent in the Mercator projection, a Lambert conformal projection should be used when long distances are involved, especially if the scale of the survey is large. World Aeronautical Charts (WAC) at a scale of 1:1,000,000 are suitable for this purpose. An alternative method is to scale the coordinates of a point near the center of the sheet and compute an inverse between the point and the station. From the computed azimuth and distance a pattern of points on the circles can be developed and their coordinates computed. The scaled distances must be expressed in terms of the units measured by the system, that is: Microseconds for EPI, statute miles for Shoran, and lanes for Raydist. The distances are then converted to meters. Table 7 can be used to convert microseconds to meters and Table 8 to convert statute miles to meters. Since lane width for the Raydist system is a function of the frequency used and is expressed in meters, no conversion table is necessary.

The geographic coordinates of the points A1, B1, C1, etc., in Fig. 51, are computed and plotted on the sheet. The radial lines should pass through the computed points along each azimuth, and a circle should

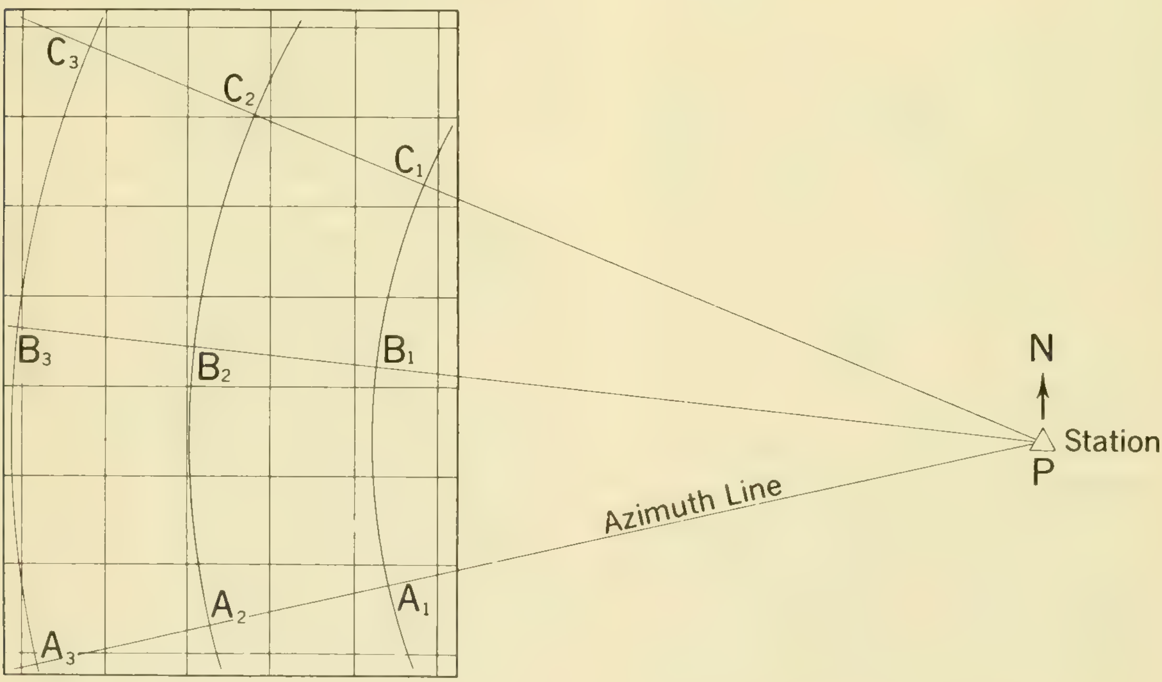


FIGURE 51.—Principle of drawing distance arcs when the station is off the sheet.

TABLE 7.—Microseconds to meters
(Conversion factor: 1 microsecond = 149.8447 meters.)

Msec	Meters	Msec	Meters	Msec	Meters	Msec	Meters	Msec	Meters	Msec	Meters
10	1,498.45	510	76,420.80	1,010	151,343.15	1,510	226,265.50	2,010	301,187.85	2,510	376,110.20
20	2,996.89	520	77,919.24	1,020	152,841.59	1,520	227,763.94	2,020	302,686.29	2,520	377,608.64
25	3,746.12	525	78,668.47	1,025	153,590.82	1,525	228,513.17	2,025	303,435.52	2,525	378,357.87
30	4,495.34	530	79,417.69	1,030	154,340.04	1,530	229,262.39	2,030	304,184.74	2,530	379,107.09
40	5,993.79	540	80,916.14	1,040	155,838.49	1,540	230,760.84	2,040	305,683.19	2,540	380,605.54
50	7,492.24	550	82,414.59	1,050	157,336.94	1,550	232,259.28	2,050	307,181.64	2,550	382,103.98
60	8,990.68	560	83,913.03	1,060	158,835.38	1,560	233,757.73	2,060	308,680.08	2,560	383,602.43
70	10,489.13	570	85,411.48	1,070	160,333.83	1,570	235,256.18	2,070	310,178.53	2,570	385,100.88
75	11,238.35	575	86,160.70	1,075	161,083.05	1,575	236,005.40	2,075	310,927.75	2,575	385,850.10
80	11,987.58	580	86,909.93	1,080	161,832.28	1,580	236,754.63	2,080	311,676.98	2,580	386,599.33
90	13,486.02	590	88,408.37	1,090	163,330.72	1,590	238,253.07	2,090	313,175.42	2,590	388,097.77
100	14,984.47	600	89,906.82	1,100	164,829.17	1,600	239,751.52	2,100	314,673.87	2,600	389,596.22
110	16,482.92	610	91,405.27	1,110	166,327.62	1,610	241,249.97	2,110	316,172.32	2,610	391,094.67
120	17,981.36	620	92,903.71	1,120	167,826.06	1,620	242,748.41	2,120	317,670.76	2,620	392,593.11
125	18,730.59	625	93,652.94	1,125	168,575.29	1,625	243,497.64	2,125	318,419.99	2,625	393,342.34
130	19,479.81	630	94,402.16	1,130	169,324.51	1,630	244,246.86	2,130	319,169.21	2,630	394,091.56
140	20,978.26	640	95,900.61	1,140	170,822.96	1,640	245,745.31	2,140	320,667.66	2,640	395,590.01
150	22,476.70	650	97,399.06	1,150	172,321.40	1,650	247,243.76	2,150	322,166.10	2,650	397,088.46
160	23,975.15	660	98,897.50	1,160	173,819.85	1,660	248,742.20	2,160	323,664.55	2,660	398,586.90
170	25,473.60	670	100,395.95	1,170	175,318.30	1,670	250,240.65	2,170	325,163.00	2,670	400,085.35
175	26,222.82	675	101,145.17	1,175	176,067.52	1,675	250,989.87	2,175	325,912.22	2,675	400,834.57
180	26,972.05	680	101,894.40	1,180	176,816.75	1,680	251,739.10	2,180	326,661.45	2,680	401,583.80
190	28,470.49	690	103,392.84	1,190	178,315.19	1,690	253,237.54	2,190	328,159.89	2,690	403,082.24
200	29,968.94	700	104,891.29	1,200	179,813.64	1,700	254,735.99	2,200	329,658.34	2,700	404,580.69
210	31,467.39	710	106,389.74	1,210	181,312.09	1,710	256,234.44	2,210	331,156.79	2,710	406,079.14
220	32,965.83	720	107,888.18	1,220	182,810.53	1,720	257,732.88	2,220	332,655.23	2,720	407,577.58
225	33,715.06	725	108,637.41	1,225	183,559.76	1,725	258,482.11	2,225	333,404.46	2,725	408,326.81
230	34,464.28	730	109,386.63	1,230	184,308.98	1,730	259,231.33	2,230	334,153.68	2,730	409,076.03
240	35,962.73	740	110,885.08	1,240	185,807.43	1,740	260,729.78	2,240	335,652.13	2,740	410,574.48
250	37,461.18	750	112,383.53	1,250	187,305.88	1,750	262,228.22	2,250	337,150.58	2,750	412,072.92
260	38,959.62	760	113,881.97	1,260	188,804.32	1,760	263,726.67	2,260	338,649.02	2,760	413,571.37
270	40,458.07	770	115,380.42	1,270	190,302.77	1,770	265,225.12	2,270	340,147.47	2,770	415,069.82
275	41,207.29	775	116,129.64	1,275	191,051.99	1,775	265,974.34	2,275	340,896.69	2,775	415,819.04
280	41,956.52	780	116,878.87	1,280	191,801.22	1,780	266,723.57	2,280	341,645.92	2,780	416,568.27
290	43,454.96	790	118,377.31	1,290	193,299.66	1,790	268,222.01	2,290	343,144.36	2,790	418,066.71
300	44,953.41	800	119,875.76	1,300	194,798.11	1,800	269,720.46	2,300	344,642.81	2,800	419,565.16
310	46,451.86	810	121,374.21	1,310	196,296.56	1,810	271,218.91	2,310	346,141.26	2,810	421,063.61
320	47,950.30	820	122,872.65	1,320	197,795.00	1,820	272,717.35	2,320	347,639.70	2,820	422,562.05
325	48,699.53	825	123,621.88	1,325	198,544.23	1,825	273,466.58	2,325	348,388.93	2,825	423,311.28
330	49,448.75	830	124,371.10	1,330	199,293.45	1,830	274,215.80	2,330	349,138.15	2,830	424,060.50
340	50,947.20	840	125,869.55	1,340	200,791.90	1,840	275,714.25	2,340	350,636.60	2,840	425,558.95
350	52,445.65	850	127,368.00	1,350	202,290.34	1,850	277,212.70	2,350	352,135.04	2,850	427,057.40
360	53,944.09	860	128,866.44	1,360	203,788.79	1,860	278,711.14	2,360	353,633.49	2,860	428,555.84
370	55,442.54	870	130,364.89	1,370	205,287.24	1,870	280,209.59	2,370	355,131.94	2,870	430,054.29
375	56,191.76	875	131,114.11	1,375	206,036.46	1,875	280,958.81	2,375	355,881.16	2,875	430,803.51
380	56,940.99	880	131,863.34	1,380	206,785.69	1,880	281,708.04	2,380	356,630.39	2,880	431,552.74
390	58,439.43	890	133,361.78	1,390	208,284.13	1,890	283,206.48	2,390	358,128.83	2,890	433,051.18
400	59,937.88	900	134,860.23	1,400	209,782.58	1,900	284,704.93	2,400	359,627.28	2,900	434,549.63
410	61,436.33	910	136,358.68	1,410	211,281.03	1,910	286,203.38	2,410	361,125.73	2,910	436,048.08
420	62,934.77	920	137,857.12	1,420	212,779.47	1,920	287,701.82	2,420	362,624.17	2,920	437,546.52
425	63,684.00	925	138,606.35	1,425	213,528.70	1,925	288,451.05	2,425	363,373.40	2,925	438,295.75
430	64,433.22	930	139,355.57	1,430	214,277.92	1,930	289,200.27	2,430	364,122.62	2,930	439,044.97
440	65,931.67	940	140,854.02	1,440	215,776.37	1,940	290,698.72	2,440	365,621.07	2,940	440,543.42
450	67,430.12	950	142,352.46	1,450	217,274.82	1,950	292,197.16	2,450	367,119.52	2,950	442,041.86
460	68,928.56	960	143,850.91	1,460	218,773.26	1,960	293,695.61	2,460	368,617.96	2,960	443,540.31
470	70,427.01	970	145,349.36	1,470	220,271.71	1,970	295,194.06	2,470	370,116.41	2,970	445,038.76
475	71,176.23	975	146,098.58	1,475	221,020.93	1,975	295,943.28	2,475	370,865.63	2,975	445,787.98
480	71,925.46	980	146,847.81	1,480	221,770.16	1,980	296,692.51	2,480	371,614.86	2,980	446,537.21
490	73,423.90	990	148,346.25	1,490	223,268.60	1,990	298,190.95	2,490	373,113.30	2,990	448,035.65
500	74,922.35	1,000	149,844.70	1,500	224,767.05	2,000	299,689.40	2,500	374,611.75	3,000	449,534.10

TABLE 8.—Statute miles to meters
(Conversion factor: 1 statute mile = 1,609.347219 meters.)

St. M.	Meters	St. M.	Meters	St. M.	Meters	St. M.	Meters	St. M.	Meters	St. M.	Meters
1	1,609.35	19	30,577.60	36	57,936.50	54	86,904.75	71	114,263.65	89	143,231.90
2	3,218.69			37	59,545.85			72	115,873.00		
3	4,828.04	20	32,186.94	38	61,155.19	55	88,514.10	73	117,482.35	90	144,841.25
4	6,437.39	21	33,796.29	39	62,764.54	56	90,123.44	74	119,091.69	91	146,450.60
		22	35,405.64			57	91,732.79			92	148,059.94
5	8,046.74	23	37,014.99	40	64,373.89	58	93,342.14	75	120,701.04	93	149,669.29
6	9,656.08	24	38,624.33	41	65,983.24	59	94,951.49	76	122,310.39	94	151,278.64
7	11,265.43			42	67,592.58			77	123,919.74		
8	12,874.78	25	40,233.68	43	69,201.93	60	96,560.83	78	125,529.08	95	152,887.99
9	14,484.12	26	41,843.03	44	70,811.28	61	98,170.18	79	127,138.43	96	154,497.33
		27	43,452.38			62	99,779.53			97	156,106.68
10	16,093.47	28	45,061.72	45	72,420.62	63	101,388.88	80	128,747.78	98	157,716.03
11	17,702.82	29	46,671.07	46	74,029.97	64	102,998.22	81	130,357.13	99	159,325.38
12	19,312.17			47	75,639.32			82	131,966.47		
13	20,921.51	30	48,280.42	48	77,248.67	65	104,607.57	83	133,575.82	100	160,934.72
14	22,530.86	31	49,889.76	49	78,858.01	66	106,216.92	84	135,185.17	101	162,544.07
		32	51,499.11			67	107,826.26			102	164,153.42
15	24,140.21	33	53,108.46	50	80,467.36	68	109,435.61	85	136,794.51	103	165,762.76
16	25,749.56	34	54,717.80	51	82,076.71	69	111,044.96	86	138,403.86	104	167,372.11
17	27,358.90			52	83,686.06			87	140,013.21		
18	28,968.25	35	56,327.15	53	85,295.40	70	112,654.31	88	141,622.56	105	168,981.46

pass through the three points at equal distance. Points on the other circles to be drawn can be located by sub-dividing the radial lines. All computations should be retained for use in constructing the smooth sheet.

The distance circles can be drawn by one of three methods. Plastic arcs of varying radii are available for drawing EPI and Shoran circles, or can be constructed if there is sufficient need to justify their cost (see 3–140). Other types of standard curves may be used. When the arcs are not long enough to permit drawing a continuous curve the full length of a sheet, four points should be computed and plotted so that the curve can be placed to coincide with three points along the arc.

If the station is only a few feet from the edge of the sheet, the station center may be located by drawing intersecting arcs from the computed points on the nearest circle. The boat sheet should be laid flat and secured in position at one end of the drafting table and a section of bristol board or other suitable material fastened to the table at the approximate location of the station. The arcs from the three nearest points should intersect at one point and should be checked from other computed points before the circles are inked.

A third method of drawing the circles is shown in Figure 52. Two pins are set firmly at positions A and B. The angle D equals $180° - \frac{1}{2}X$ and this holds true for any point along the arc AB. The angle D is set on a metal protractor using the movable arm that can be closed to a zero reading. A pencil is centered in the protractor and the arc is drawn by moving it along with the arms sliding against the pins. The arc BC can be drawn in a similar manner using the angular difference in azimuths of the lines PB and PC as X. The portion of the arc that falls beyond A or C is plotted with the protractor set at $\frac{1}{2}X$. This method is approved for boat sheet plotting only.

5–12 Distance circle intervals.—Odessey protractors (see 3–22) are used to plot positions determined by electronic ranging systems. Although protractors can be constructed to fit any desired interval of distance circles, the general practice is to draw the circles at intervals which are approximately equal to latitude projection intervals so that the protractors will be of moderate size and easy to manipulate. The spacing of the distance circles with relation

to the scale of the survey should be according to Table 9. The spacing of Raydist distance circles shown in the table is suitable for presently assigned frequencies and may be changed when different frequencies are employed.

5–13 Circle sheets for plotting sextant fixes.—Since electronic positioning equipment has been adapted to control of hydrographic surveys, the use of visual control methods is limited almost exclusively to inshore surveys. Sextant fixes can be plotted with three-arm protractors quickly and easily in most instances. However, the hydrographer may at times be required to use long extensions on a protractor when plotting sextant fixes on large scale surveys. This is a time consuming procedure; and, if the projection is distorted, the plot will be inaccurate. To facilitate the plotting and avoid inaccuracies due to distortion, a system of intersecting arcs of circles, sometimes called circles of equal angle, may be drawn on the sheet, each circle being the locus of some angle between two control stations. A position may then be plotted at the intersection of the loci of the two observed angles, each locus being found by interpolation between the adjacent arcs drawn on the sheet. A control station common to both angles is ordinarily used, but this is not necessary.

Circle sheets have been used extensively in the past to plot large scale offshore surveys although few if any of the signals could be plotted on the sheet. Modern survey practices are such that this condition should rarely exist, therefore only the simplest form of the problem will be discussed, that is; when all stations and the lines of centers fall on the sheet.

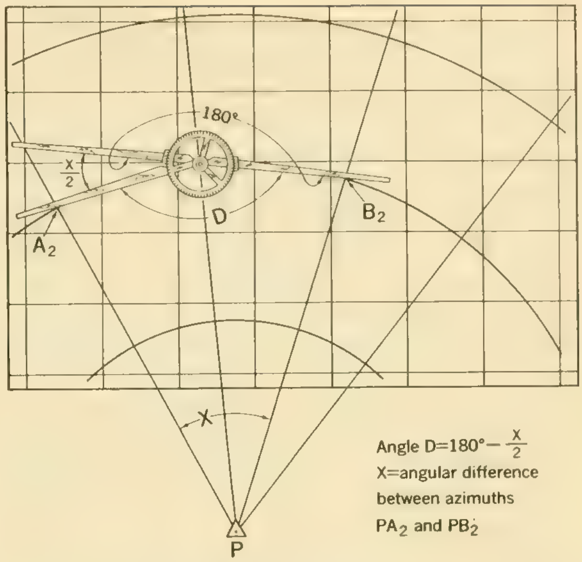


FIGURE 52.—Drawing arcs with a metal three-arm protractor.

To construct the circles, scale or compute the distance "*a*" between the two stations A and B (Fig. 53) and plot the mid point "D" of the line joining the two stations. Erect a perpendicular at the mid point. The center of any circle generated by an angle α is on this line at a distance "*d*" from the mid point "D" and the radius of the circle is apparent. Compute "*d*" distances for the range of angles required by substituting in

TABLE 9.—Distance circle intervals and units

Scale of Survey	*Circle Intervals and Units*		
	Shoran	*EPI*	*Raydist*
1:10,000	1 Sta. Mi		20 Lanes.
1:20,000	1 Sta. Mi		50 Lanes.
1:30,000	2 Sta. Mi		100 Lanes.
1:40,000	2 Sta. Mi		100 Lanes.
1:60,000	5 Sta. Mi		200 Lanes.
1:80,000	5 Sta. Mi	50 Microseconds	200 Lanes.
1:100,000	5 Sta. Mi	50 Microseconds	200 Lanes.
1:120,000	5 Sta. Mi	50 Microseconds	200 Lanes.
1:160,000	10 Sta. Mi	100 Microseconds	400 Lanes.
1:200,000		100 Microseconds	400 Lanes.
1:300,000		200 Microseconds	
1:400,000		200 Microseconds	
1:500,000		250 Microseconds	
1:800,000		500 Microseconds	

the formula $d = X \frac{a}{2} \cot \alpha$, in which X is a scale factor introduced so that the results can be measured directly on a 1:10,000 scale meter bar. For any scale the scale factor $X = \frac{10{,}000}{\text{scale used}}$ Thus if the scale is 1:20,000, $X = \frac{1}{2}$. See Section 7–31 and Table 18 for natural half-cotangents.

After the centers have been computed and plotted, a system of arcs is drawn with a beam compass using a distinctive color of ink for each set of circles. The circles are numbered in the same color ink to indicate the angle each represents. The maximum distance between concentric circles should not exceed three inches. A check on the plotting is obtained if a circle passes through the center of a circle of half that angle.

A little time is required to compute the data and plot the arcs, but the ease of plotting positions will soon establish the advantages of the system. All hydrographers are encouraged to make wider use of this method where appropriate. All computations should be retained for use when plotting the smooth sheet.

5–14 Transfer of topographic details.—A boat sheet for any inshore survey shall contain the high water line, and all available information concerning alongshore and offshore rocks, aids to navigation, channels, approximate limits of shoal areas, and positions of reported dangers to navigation. The two principle sources of such information are the published charts and topographic manuscripts. The hydrographic party will be furnished photogrammetric manuscripts or copies of prior planetable topographic surveys. Classification of photogrammetric manuscripts and their uses are explained in Chapter 4.

After the positions of known signals have been plotted on the boat sheet, the high water line and all details seaward thereof shall be transferred to it. Reverse blueline tracings on vinylite of all photogrammetric manuscripts will be furnished. Shoreline and other details are transferred to the boat

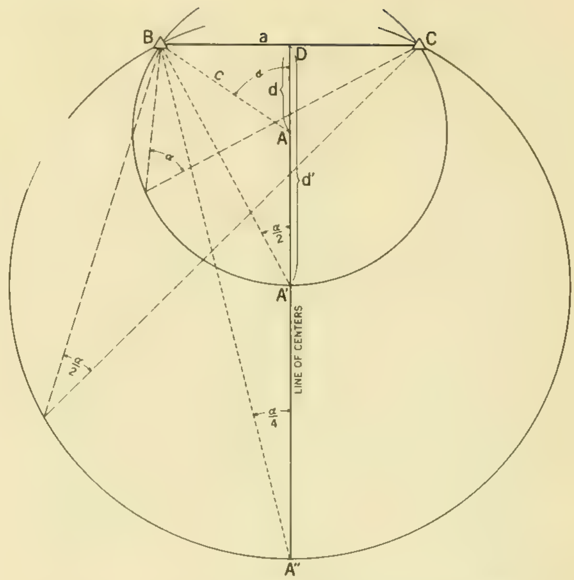


FIGURE 53.—Principle of plotting angles without a protractor.

sheet by burnishing the tracing after the projection intersections have been properly matched. Film positives of planetable surveys are furnished when photogrammetric maps are not available. Details may be transferred by applying "dri-rite" ink on the reverse side, matching projections, and tracing the shoreline with a stylus or pencil. Shoreline is not required on boat sheets for offshore surveys, especially where scale changes are necessary to accomplish the transfer.

After the transfer of data from the manuscripts or topographic sheets has been verified, the station symbols should be inked (see 5–10) and the shoreline inked in black. Offshore rocks and limits of kelp or foul areas transferred from photogrammetric manuscripts should be inked in blue on the boat sheet at the time of transfer and inked in black after verification of position and character by the hydrographic survey (see 5–67).

5–15 Transfer of data from prior surveys.—All dangers to navigation, including least depths on shoals, shall be transferred to the boat sheet from copies of prior hydrographic surveys, if any have been made,

and inked in distinctive colors. Representative soundings in the area shall also be transferred. It is desirable to transfer sections of depth curves which, with the soundings, provide a direct comparison with previous surveys.

The most recent print of the largest scale nautical chart covering the area should be examined and any additional dangers shown thereon shall be transferred to the boat sheet for verification as the survey progresses.

A presurvey review (see 1–5 and 6–108) will usually be furnished for each project. Each feature marked on the chart shall be transferred to a boat sheet and examined during the survey.

The positions of any locally reported shoals or menaces to navigation should be plotted on the boat sheet, so that their position may be accurately determined or their existence disproved.

Soundings and other hydrographic data transferred to the boat sheet may be obliterated or obscured while surveys are in progress. As an aid to daily inspection of the survey, an overlay should be prepared on tracing cloth showing all data transferred to the boat sheet from the charts or prior surveys (see 5–66). As the survey progresses critical data can be transferred to the overlay, as: least depths on shoals, locations of rocks, breakers, obstructions, etc., with appropriate notes for future reference. Used in conjunction with the smooth sheet, the overlay provides a quick check on the completeness of the plotted data.

5–16 Junctions and overlaps.—To insure satisfactory junctions in coverage and depths with adjacent surveys, the soundings at the limit of the latter shall be transferred to the boat sheet prior to the beginning of a hydrographic survey. These soundings shall appear in colored ink, using a different color for each survey with which a junction is to be made. These soundings may be from prior surveys or surveys currently made on adjoining sheets of the same or different scales. In areas where the Corps of Engineers, U.S. Army, maintains dredged channels, soundings from the most recent Engineer survey may be transferred to the boat sheet, and, if a satisfactory junction is made, the survey of the channel need not be repeated (see 5–2).

The source of soundings at junctions should be noted on the boat sheet by reference to the field or registry number of the survey, or the identifying number of the Corps of Engineers survey.

An overlap of at least one sounding line shall be made with an adjacent survey (see 1–29) except where the survey is continuous in the same year by the same method and by the same survey vessel no overlap is required. If the depths at the junction are not in agreement, the new survey shall be extended into the old until agreement is reached. If a reasonable extension fails of agreement, a detailed report shall be submitted to the office with a request for further instructions.

The best evidence of a proper junction of surveys is revealed by the continuity of the depth curves in the overlap area (see 5–74).

5–17 Inshore limits of surveys.—In protected waters the hydrographic survey shall extend as close to the high-water line as practicable. The low-water line should be fully developed by the survey in all areas where existing conditions permit. Sounding lines should be run close to the shore during periods of high tide and calm weather. Complete development of extensive mud flats is not required. A few sounding lines spaced at 3 to 4 times the maximum spacing of lines in the adjacent area will suffice. Soundings are not required in areas which are bare at low water.

Within the project limit all streams shall be surveyed to the head of navigation for small boats, and all tidal sloughs and estuaries to the same limit or until the low-water line has been accurately delineated, unless the project instructions specify otherwise.

On open exposed coasts the hydrography should extend as close to the high-water line as possible without undue risk to safety of the boat and personnel. It is always desirable to develop the low-water line, but this is impossible in many places. Along regular

sandy beaches, lines should be run parallel to the shore during periods of high tide and calm weather. In areas of very small range of tide, such as the Gulf of Mexico, there may be a wide band of very shoal water offshore from the low-water line which is difficult and uneconomic to develop. In such areas the inshore lines should be run as close to the shoal as possible, and the hydrography supplemented by a few widely spaced soundings obtained from a skiff or by wading at low water.

On rocky coasts it is frequently impracticable to delineate the low-water line even in part. Where it is dangerous for the sounding launch to enter a rocky area along the shore, or where kelp is so thick that the sounding boat cannot navigate through it, the facts should be stated in the record book and the area accurately outlined on the boat sheet with appropriate notes added.

Before attempting to run sounding lines in rocky inshore areas, the hydrographer should examine the area at low-water, preferably at low spring tide, and locate by sextant fixes or cuts all breakers and exposed rocks. Sounding lines may then be run at high tide with a greater degree of safety.

In all cases when the low-water line cannot be delineated by the hydrographic survey, the areas should be fully described in the descriptive reports with an explanation of the conditions preventing the extension of the survey close inshore. Copious notes in the record book and on the boat sheet should be made to show the limits of breakers, kelp, or foul areas which prevented closer approach to the shore.

5–18 **Sounding.**—The various devices by which depth may be measured in hydrographic surveying are described in Chapter 3, and the general depths in which each is to be used is specified in 1–35. Soundings should always be obtained by a graphic recorder whenever possible, since this type of instrument yields a permanent record and a continuous profile of the bottom. When sounding in areas where kelp or other varieties of bottom cover partially or totally obscure the bottom trace, a leadline or sounding pole must be used to supplement or replace echo soundings. Hand lead or wire soundings must be true vertical measurements. When bottom samples are being taken, the soundings should not be recorded if the wire or leadline is sloping. Such soundings only cause confusion in later processing unless the discrepancies are fully explained in the record.

Echo sounders record soundings with a consistency and accuracy which is directly related to the care with which the instruments are maintained and operated. If there is doubt as to the accuracy of the soundings, or control, for whatever reason, the sounding line should be broken immediately and should not be resumed until all uncertainties have been resolved. To continue on line under such circumstances is usually a waste of time and often introduces unnecesssary complications in processing (see 5–75). The hydrographer should remember that the recording of a sounding is only the first operation in a lengthy process of publishing it on a nautical chart.

The depths of water shall be measured with the greatest accuracy consistent with efficient progress. No depth-measuring instrument or method shall be used to sound over relatively even bottom or in critical depths which does not measure depths less than 11 fathoms accurately within one half foot, and greater depths within one percent, unless specifically authorized by the Director.

In rapidly changing depths and over irregular bottoms the requirements may be lowered to 1 foot for depths less than 11 fathoms. It is recognized that echo soundings in a submarine valley or on a steep slope may be less than the vertical depth under the vessel, particularly when a low frequency echo sounder is used. Slope corrections are not required.

5–19 **Systems of sounding lines.**—It is obviously impossible to measure the depth at every point in the water area. A methodical and systematic examination of an area is best accomplished by running a system of parallel sounding lines (see 1–24). The purpose of the regular system of lines is: first, to furnish a realistic representa-

tion of the sea bottom and submarine relief; and second, to reveal indications of shoals or submerged dangers which are subsequently investigated for least depths (see 1–27 and 28).

Generally a system of lines normal to the depth curves provides the most convenient and economic development of any area, but it is often more advantageous to adopt some other system for various reasons. The system adopted for an open coast is not necessarily suitable for bays and harbors. The development of steep features such as submarine ridges and valleys should be accomplished by a system of lines which cross the depth curve at an angle of approximately 45 degrees. The selection of the most appropriate systems of lines for any given area is governed by the type of control used, the configuration of the area, and its location with respect to an anchorage or base of operations. Three systems of sounding lines are in general use: (a) parallel straight lines; (b) radiating lines; and (c) concentric arcs (Fig. 54).

5–20 Systems of parallel straight lines.—A system of evenly spaced parallel lines normal to the depth curves and general trend of the shore line is most frequently used especially along an open coast. The principal advantages of such a system are that the best delineation of the depth curves is obtained with a minimum of sounding lines; three-point fixes are more easily obtained since fewer changes in objects are required; a position close inshore, which cannot be fixed by sextant angles, can be reasonably well determined by course and distance from the last fixed position; and ranges on shore can be used to advantage in running the lines. The principal disadvantages of this system are that it is difficult to extend the lines close to the shore, and dangerous when heading inshore; variations in speed at the inshore ends may cause displacement of soundings and lines of varying lengths must be run appropriate to variation in depths.

When this system is adopted two or more lines should be run parallel to the shore and at high tide during calm weather. One line should be as close to the shore as circumstances permit, having due regard for the safety of the launch. The second line should be spaced about 50 meters offshore from the first, and additional lines may be run as necessary to provide a sounded zone for the launch to turn in when running lines normal to the shore.

When the coastline has an even trend and a gradually sloping bottom, a system of lines parallel to the shore may be used. In this case the line spacing is gradually increased as the depth increases. When such a system is used, longer lines may be run and there is less danger to the launch since the inshore lines are run when sea conditions are best. More frequent changes of fix are required and the development of depth curves is less accurate when this system is used. A system of lines parallel to the coast is impracticable where the shoreline is very irregular or has many indentations. Unless the control stations are some distance inshore from the high water line, fixes on the inshore line are apt to be weak since one angle is generally very large and the other small and both change very rapidly.

A system of straight parallel lines, whose direction is at 45° to the depth curves, is of advantage in certain areas. For the same spacing between lines, such a system provides a better development of long, narrow, steep-sided ridges or troughs.

5–21 Systems of concentric arcs.—A system of parallel arcs of circles may be used to great advantage in some areas where Shoran or Raydist equipment is used to control the survey. Such a system can be run at any desired spacing by steering the sounding vessel along a pre-selected arc of a circle which is centered on the shore station. The position of the vessel on the arc is fixed by its intersection with the distance arc from a second station. Course changes are required at intervals depending on the speed of the sounding vessel and the rate of curvature of the arc. After a little practice the Shoran or Raydist operator is able to keep very close to the arc at all times.

This efficient system has two important ad-

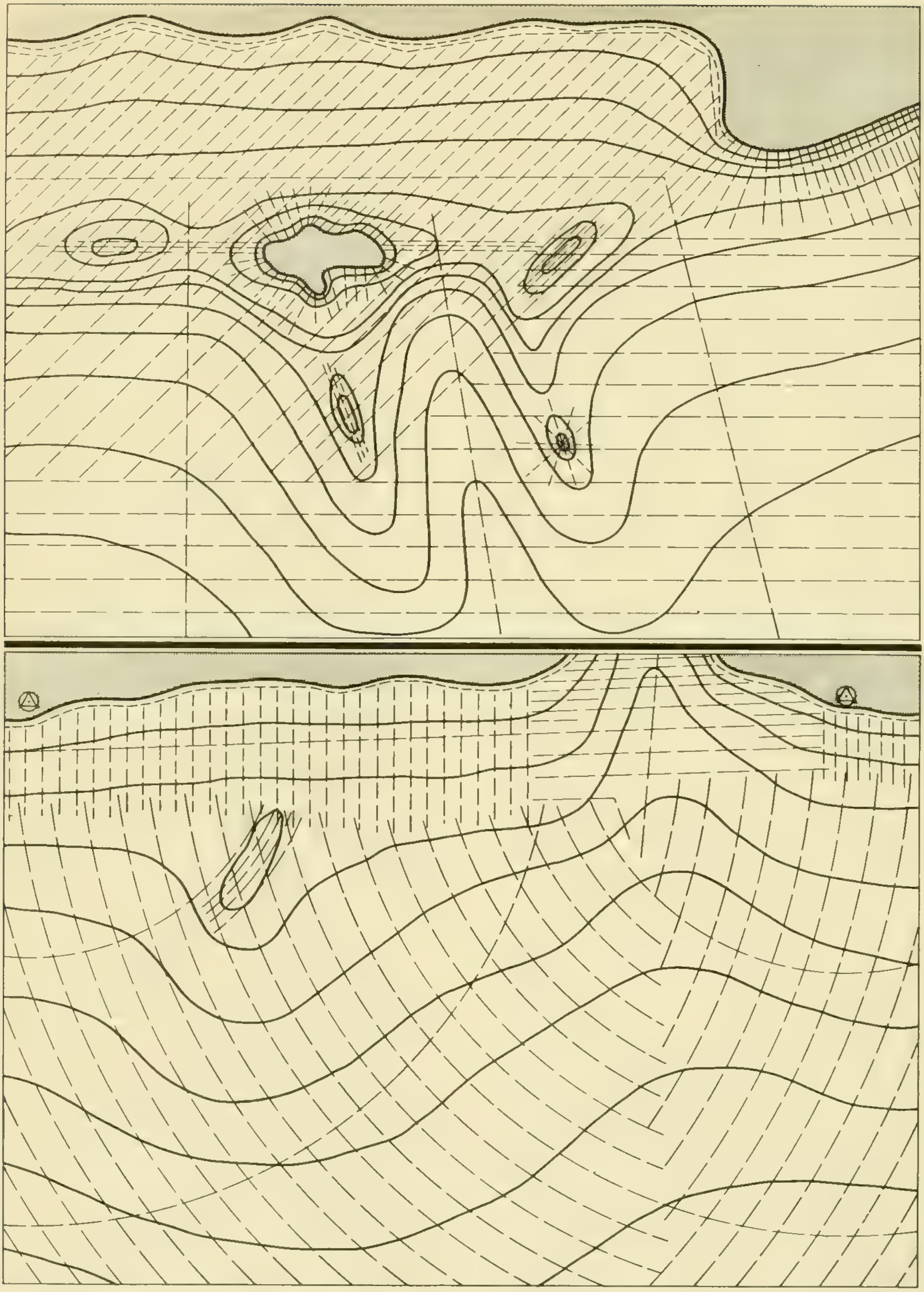


FIGURE 54.—Systems of sounding lines. The solid lines represent depth curves, and the broken lines represent appropriate systems of sounding lines for the various conditions encountered.

vantages; first, the effects of current can be observed directly and corrections applied to maintain the desired line spacing; and second, sounding line spacing can be reduced by running "splits" at any desired interval. When properly used the maximum line spacing for the depth can be used and the control is so positive that this maximum should seldom, if ever, be exceeded. Since lines can always be run exactly where they are proposed, very few lines are wasted.

When this system is used the hydrographer has a choice of paralleling segments of two sets of arcs. He should select the set which will provide the most efficient coverage of the area and best development of submerged features. The system is most suitable for inshore hydrography in wide passages, in areas where offshore islands are available for shore stations, and in wide bays or estuaries. It may be used by ships in offshore surveys where the bottom slope is slight, but should generally not be used where sounding lines pass over steep slopes at an angle less that 45°.

A system to provide automatic steering along an arc has been developed but is not in common use. Information is furnished by the Shoran or Raydist to the gyro-pilot which responds to bring the ship to the proper distance from the shore station.

5–22 Systems of radiating lines.—Off points where there is a marked change in the trend of the shoreline, in small bays and around off-lying islets, radiating lines generally provide the most adequate development. These are merely special cases of systems designed to provide sounding lines normal to the shore, and, because of their divergence, they are comparatively short lines. It is sometimes convenient to develop a shoal of small extent by running a system of radial lines crossing in the vicinity of a temporary marker buoy planted near the center of the shoal.

5–23 Cross lines.—In addition to the regular system of sounding lines adopted to accomplish the survey, a second, but not less important system of lines must be run on most surveys. These are the cross lines which are designed to disclose discrepancies in the regular system of soundings. Such discrepancies may arise from the use of a faulty plane of reference, inadequate or weak control, an operational failure of the echo sounder, or unusual tide levels caused by strong winds. Crosslines shall be run as specified in 1–26.

The shallow water sounds and bays along the Atlantic and Gulf Coasts are subject to unusual tides as a result of strong winds. if a system of cross lines is run first in such areas as directed in 1–26(e), and under normal condition of wind and sea, abnormal tides will be reflected by poor crossings. The tide observing program can be supplemented by a short series of observations on a staff in the immediate vicinity, or an arbitrary correction can be deduced with reasonable accuracy by comparison of soundings at crossings.

5–24 System of sounding lines in channels.—The limits of narrow channels should first be defined by a series of cross lines which may be run normal to the axis or diagonally across it. In either case, extreme care is required in order to avoid displacement of depth curves on steep slopes. Variations in speed at the beginning and ending of short cross lines, if not properly plotted, produce inaccuracies which are indicated by unnatural waves in the depth curves along the edge of the channel.

After the limits of the channel have been established, it must be completely developed by a system of closely spaced lines parallel to the axis of the channel. If the channel is marked by a range, it is essential that a line of soundings be run exactly on the range line.

Most dredged channels are maintained by the Corps of Engineers, but some are privately maintained. Nautical charts contain the latest available information on dredged channels as to project depths and controlling depths on a certain date. Data on primary channels are usually published in tabular form in which the least depth is given for

the right and left quarter and center half of the channel or for each quarter of the channel width. When the hydrographic survey reveals that shoaling is taking place in a channel by amounts which may present a hazard to ships using it, the Chief of Party should notify the nearest office of the Corps of Engineers. Copies of all correspondence and sketches shall be forwarded to the Director.

5–25 Spacing sounding lines.—The proper spacing of sounding lines depends on the depth of the water, character of the submarine relief, scale of the survey, and the importance of the area being surveyed. The general spacing of lines should give a representation of the depths and generalized depth curves in the area, and should be sufficiently close to give indications of all submerged dangers. The general spacing must be reduced wherever necessary to fully develop all bottom relief and to obtain the least depth on shoals, banks, and pinnacles (see 1–25).

The project instructions usually specify the maximum spacing which may be used in various depths or areas. The hydrographer, or the chief of party, should reduce the line spacing as necessary in critical areas to accomplish a complete hydrographic survey, but the general spacing specified in the project instructions shall not be increased or decreased over large areas without prior approval of the Director. If the Chief of Party is of the opinion that the general spacing should be changed, he should submit a full report in support of his request for an amendment to the instructions.

There is a practical limit to the number of lines of soundings which can be plotted at any given scale. In general, four of five sounding lines to the inch can be plotted and the soundings inked without difficulty. With a little more care in plotting and selection of soundings to be plotted, the number of lines can be increased to 7 or 8 to the inch. Lines plotted in excess of this number seldom contribute significantly to the survey. After the bottom configuration has been well developed, the hydrographer may find it desirable to run many more short lines over a shoal in an effort to determine the least depth on it. These lines should be plotted on the boat sheet or an overlay, but, unless they furnish new information not supplied by the other lines, the positions on the extra lines should be clearly marked "not to be smooth plotted" and the reasons stated (see 1–28). Such lines are not to be rejected and the fathograms and other pertinent data shall be forwarded with the records. The fathograms must be carefully studied first to make certain that the least depth is not overlooked.

When the bottom consists entirely of mud or sand, its slope will not, as a rule, be very great at any point and a shoal must therefore occupy a considerable area in porportion to its height. It is unlikely that a shoal involving any great change in depth could lie wholly between two adjacent lines and so remain undetected. Conversely, where the bottom is rocky, sharp irregularities must be expected and every shoal indication must be examined. Though a shoal is usually indicated by a decrease in depth, it is also necessary to regard unexpectedly deep soundings with suspicion since they may mark the scour which is caused by the currents beside a rock or other obstruction rising steeply from the bottom. Side echoes may be recorded on the fathogram in such cases.

5–26 Line spacing in harbors.—In harbors, bays, passages, channels, and rivers the general rule is that the maximum spacing of sounding lines is: 100 meters in depths less than 11 fathoms; 200 meters in depths from 11 to 30 fathoms; and 400 meters in greater depths. In narrow channels, either dredged or natural, the line spacing shall not exceed 50 meters. Soundings shall be obtained along the faces of all piers and in the berthing areas adjacent thereto (see 5–83).

If the area is of sufficient importance to require a survey at a scale of 1:5,000, the sounding lines shall be spaced at intervals of 50 meters.

In all cases, the sounding line spacing must be reduced as necessary to develop shoals and ascertain the least depths on them, and to provide soundings in sufficient numbers

to permit an accurate portrayal of the bottom configuration.

5–27 Line spacing on open coasts.—The spacing of sounding lines on open coasts depends on the depth of water, type of bottom, and scale of the survey. In areas such as the Gulf of Mexico and parts of the Atlantic coast where the bottom is composed mostly of sand or mud and depths increase slowly, sounding lines can usually be spaced at twice the interval which can be safely used in areas of irregular bottom. In areas of smooth bottom, along an open coast a line spacing of 200 meters in depths less than 11 fathoms, 400 meters in depths or 11 to 20 fathoms, and 800 meters in greater depths will be adequate However, at entrances to harbors, in areas adjacent to spits or rocky points, and in areas where major changes in bottom contours are found, the spacing shall be reduced one-half.

In areas of irregular bottom on open coasts the line spacing shall not exceed: 100 meters in depths less than 20 fathoms around rocky points and spits and in entrances to channels; 200 meters in all other areas where the depth is less than 20 fathoms; 400 meters in depths of 20 to 30 fathoms and 800 meters in depths of 30 to 50 fathoms.

5–28 Line spacing for offshore surveys.—Hydrographic surveys in offshore areas may be plotted on scales as large as 1:40,000 where they join inshore surveys, or may be plotted on a scale as small as 1:500,000 in ocean areas of great depth. Regardless of the type of bottom the line spacing shall not exceed: 1,600 meters (1 mile) in depths of 50 to 100 fathoms; 3,200 meters (2 miles) in depths of 100 to 500 fathoms; and 5 miles in greater depths. The nature of the bottom, the importance of the area, and the scale of the survey, will be considered when project instructions are written. In areas of rocky or broken bottom, closer spacing will be required and different break-points may be specified. The spacings specified above are maximums which must not be exceeded.

It is obvious that such wide spacing is not adequate to permit detailed contouring of the bottom. The surveyor must study the soundings to detect indications of submerged features which must be surveyed in greater detail. The general line spacing prescribed for the area or depth shall be reduced as necessary to determine the configuration of submerged mountains, valleys, trenches, and canyons and to determine the limits of escarpments. Smaller features such as mounds, seaknolls, and depressions should be developed. Any breaks in slopes along continental or island shelves should be defined.

5–29 Sounding interval.—Although graphic recording echo sounders are used to obtain a continuous profile, it is the usual practice to record soundings at fixed intervals as the lines are run. The hydrographer shall select a time interval for recording soundings appropriate to the scale of the survey, the depth of water, the configuration of the bottom, and the speed of the sounding vessel (see 1–33). Where the depths are uniform or the slope is uniform, the maximum interval between recorded soundings shall be that which will permit plotting all soundings on the smooth sheet without congestion (see 6–59).

In areas of irregular submarine relief, too much importance must not be attached to the maintenance of a uniform interval. A uniform interval facilitates the plotting of the smooth sheet, but it is more important that the recorded soundings give a true representation of the irregularities of the profile. In such areas the least depths must be recorded and between them the deepest depths with as many intermediate soundings as are required to define the profile accurately. At least as many soundings shall be recorded as can be shown on the smooth sheet. In order that a sounding may be plotted in its correct position, it is essential that the exact time of observation be recorded. Times of positions and regular interval soundings shall be recorded from the sounding clock. The time of an extra or odd interval sounding shall be scaled from the fathogram and shown as a fraction of the regular sounding interval (see 5–95).

The following rules will serve as a guide to the selection of the sounding interval:

(a) Where the horizontal axis of the numeral approximately parallels the direction of the sounding line, 1-digit numerals should be spaced about 6 to an inch, 2-digit numerals about 4 to an inch, and 3-digit numerals about 3 to an inch.

(b) Where the horizontal axis of the numerals is approximately normal to the direction of the sounding line, numerals should be spaced 3 to 6 to the inch depending on the depth.

(c) Where numerous decimals or fractions are to be shown these may be considered as equivalent in width to about one half digit.

With these rules as a guide, the hydrographer should select a sounding interval which, when the soundings have been plotted, will accurately portray the bottom configuration. The recording of an excessive number of soundings is wasted effort, and the waste is compounded in every phase of subsequent processing, verification, and inking (see 6–59).

5–30 Depth units.—The depth units to be used in various areas and depths are specified in Section 1–38 and Table 2. Soundings shall always be recorded in fathoms and decimals, or feet and decimals; fractions shall never be used. Ocassionally it is advisable to record soundings in fathoms in part of the area being surveyed and in feet in other parts. The record should indicate which unit is being used (see 5–95). Only one unit, feet or fathoms, shall be used when plotting soundings on the boat sheet.

5–31 Fathograms.—The graphic recording of a bottom profile produced by any type of echo sounder is called a fathogram. The profile must be correlated with other recorded data. Stamp No. 31, Graphic Record, is used for this purpose (Fig. 55). The stamp shall be impressed at each end of the fathogram and the required information entered in all spaces.

Each echo sounder is provided with a fix marker button, which, when pressed, will cause the stylus to draw a line across the paper. At each fixed position along a sounding line and at each detached position where a sounding is recorded, the echo sounder operator shall make a fix mark, and the position number shall be shown beside it. When a fix is rejected or missed, the fact shall be indicated by one or more crosses on the fix mark. The day letter should be shown at intervals of about 10 positions (see 5–55).

No. 31 GRAPHIC RECORD
Sheet No Hy 20-2-60 Recorder No. 29
Locality Davis South Shoal
Vessel Launch No. 2
From Pos. No. 1f Date 6-14-59
To Pos. No. 176f Date 6-14-59
Jagged profile (not) caused by seas.
J. P. Owen Operator
Tide reducers by ____ Checked by: ____

FIGURE 55.—Stamp used to identify fathograms.

In order that the fathogram may be properly related to the hydrography, the operator shall make notes on the record to indicate where a line begins, turns, ends, or breaks.

Each echo sounder records depths in more than one phase depending on its design. The EDO 255 and 808 type recorders have four phases and record on paper which has four scales. The first, or A phase is always identified by the initial trace, but all other phases must be identified by notes on the fathogram and in the record book. Each change of phase must be noted and recorded and the phase in use indicated on the fathogram. A circle can be drawn around the number at the top of the scale being used, or a note may be written on the fathogram to indicate each change of phase.

When the EDO–185 is being used with more than one stylus, the fathogram must be marked "+600" when the second stylus is recording the depth, or "+1200" when the third stylus is recording (see 3–79).

The Precision Depth Recorder (PDR) records in 400-fathom phases automatically. It is important that each phase be identified. The initial trace will be recorded as on other types of fathograms, however, there is no printed scale and all soundings are re-

ferred to a base line which is a multiple of 400. The value of the baseline is noted at each change by such an expression as 400 plus, 800 plus, etc., (see 3–83).

5–32 Care of fathograms.—The fathogram is the original record of the soundings and must be carefully preserved (see 1–37). Fathograms can be stored on spools but it is preferred that they be folded in accordion folds and filed in manila envelopes, or bellows files. The envelops or files shall be labeled to show their contents by sheet number, sounding vessel, and date or day letter of each fathogram.

Fathograms shall be carefully packaged and forwarded by registered mail or express. They shall not be transmitted in the same shipment with the smooth sheet or sounding record books (see 7–24.).

5–33 Position fixing.—In order that a sounding may be charted in its correct latitude and longitude or in proper relation to the adjacent shore, it is necessary to determine the position of the sounding vessel at frequent intervals. If the vessel is proceeding at a constant speed, and on a fixed course, the soundings between positions can be spaced and plotted quite accurately. The position is generally determined by one of two methods: (1) Three-point sextant fixes; or (2) simultaneous measurement of two distances to shore stations. Occasionally a position may be expressed as an estimated distance and direction from a nearby signal or other known point.

5–34 Position identification.—For proper identification, hydrographic positions shall be numbered consecutively, starting with number 1 for each sounding vessel at the beginning of each day, and each day's work shall be identified by a letter, or combinations of letters assigned in alphabetical order (see 1–31). When hydrography is continuous, on a 24-hour basis, the first position after midnight shall be considered to start a new day and shall be numbered and lettered accordingly, except for long dead reckoning lines which are often given one day letter for each line.

When a sounding line is continued from one sheet to another and the last position on one sheet is the same as the first position on the other, the position shall be identified by number and letter appropriate to each sheet.

5–35 Day letters.—Each day's hydrography shall be identified by a letter assigned in alphabetical order starting with the letter A on each sheet and omitting the letters O and I. Until the alphabet is exhausted, single letters shall be used. After the letter Z, double letters shall be used, the first series being AA, BA, CA, etc., the second series being AB, BB, CB, etc., and likewise for successive series as needed.

Capital letters of one color shall be used to identify the hydrography surveyed from the ship or major survey vessel of the party; and lower case letters to identify the work of the launches or supplementary vessels of the party, a different color being assigned to each unit. A separate series of day letters shall be used to identify the work of each sounding vessel in the records and on the sheet. The colors to be used to ink the position numbers and day letters are purple, blue red, and green in that order of preference. The day letter in the sounding record shall be recorded in the color assigned that unit (see 1–31).

5–36 Frequency of positions.—The frequency of positions along a sounding line is influenced by several factors: the scale of the survey; line spacing; speed of the survey vessel; conditions of wind and current; and type of control being used (see 1–30). The maximum distance between successive positions on a sounding line should be about 1½ inches on the survey sheet, regardless of the scale. Positions should be obtained at regular intervals as this will be of advantage in plotting and spacing soundings and will aid in detecting errors in plotting.

When sextant fixes are used to control the hydrography, positions must be obtained more frequently were there is difficulty in keeping on line due to currents or where lines must be closely spaced. Positions may be

taken less frequently when steering ranges or when the lines are being run parallel to distance arcs. In areas of even bottom the distance between successive fixes along distance arcs may be slightly increased, but should never exceed 2 inches on the sheet.

In most cases a survey ship or launch proceeds along a sounding line at full speed. If the scale of the survey is small, the positions may be taken at intervals of several minutes, however, if the scale is large the intervals will be short and it may be necessary to reduce the speed of the vessel.

Sextant fixes can be observed and plotted very rapidly particularly where the fixes are strong and the signals are nearby. Recording of an excessive number of fixes should be avoided in order to reduce the labor of smooth plotting the survey. For example, a 1½-minute interval between fixes should not be used if a 2-minute interval is adequate.

In addition to the evenly spaced positions along a sounding line, numbered positions shall be recorded under all of the following circumstances, whether or not accompanied by control data, when this is practicable:

(a) At the beginning and ending of each line.

(b) Whenever the speed of the sounding vessel is changed appreciably.

(c) At all changes of course larger than 10°. When the vessel is small and the change in course is immediately effective, the position may be taken at the middle of the change. Otherwise, a position should be recorded just before the course is altered and just as soon as the vessel is on the new course.

(d) At each detached sounding, particularly when determining the least depth on a submerged feature.

(e) Each time a bottom sample is obtained with the vessel stopped, whether or not a sounding is recorded.

(f) Each time a position is fixed for any purpose in connection with the survey, such as for determining the position of a floating aid, an obstruction, or a signal. Positions recorded for the sole purpose of calibrating electronic equipment need not be numbered.

5–37 **Three-point sextant fix.**—Most inshore hydrographic surveys are controlled by the three-point fix method using sextants to measure two angles between points whose geographic positions are known (see 3–13). The position at which the angles are observed is fixed by the intersection of two circles generated by the loci of the angles. In practice the three-point problem is solved mechanically by using a three-armed protractor. The fix is strongest when the circles intersect at an angle of about 90°, and is weakest when the two circles approach coincidence.

5–38 **Selection of objects.**—An experienced hydrographer can estimate the strength of a fix at a glance, and is able to select the strongest available fix immediately. Beginners often have difficulty is visualizing the problem and may select a weak fix when good ones are available. The following general rules apply in selection of objects to be used:

(a) The strongest fix is when the observer is inside the triangle formed by the three objects. And in such case the fix is strongest where the three objects form an equilateral triangle, the observer is at the center, and the objects are close to the observer.

(b) The fix is strong when the three objects are in a straight line, or the center object lies between the observer and a line joining the other two, and the center object is nearest to the observer.

(c) The sum of the two angles should not be less than 50°, better results being obtained when neither angle is less than 30°.

(d) The fix is strong when two objects a considerable distance apart are in range and the angle to the third is not less than 45°.

(e) A fix is strong when at least one of the angles changes rapidly as the survey vessel moves from one location to another.

(f) Small angles should be avoided as they result in weak fixes in most cases and are difficult to plot. However, a strong fix is obtained when two objects are nearly in range and the nearest one is used as the center object. The small angle must be measured accurately.

(g) The distance between the center ob-

ject and the left and right-hand objects should be longer than the distance from the observer to the center object.

Beginners should demonstrate the validity of the above rules by plotting examples of each and their opposites. It should be noted that a fix is strong if, in plotting, a slight movement of the center of the protractor moves the arms away from one or more of the stations, and is weak if such movement does not appreciably change the relation of the arms to the three points. An appreciation of the accuracy required in measuring the angles can be obtained by changing one angle about 5 minutes in each example and noting the resulting shift in the plotted positions.

Avoid a selection of objects which will result in a "revolver or swinger." Do not observe an angle between objects of different elevation if the inclined angle would require a correction of more than two minutes to reduce it to a true horizontal angle (see 3 15). Indefinite objects such as tangents, hilltops, and other poorly defined or located points should not be used.

5–39 Change of fix—Generally the strongest fix available should be used at each position. However, there are other practicable limits which govern selection of a fix. Frequent changes of objects are conducive to recorder's errors as well as observer's errors. It is better to use signals which can be positively identified rather than less distinct signals which would provide a somewhat stronger fix. Some observers tend to use the same object long after a change to a stronger fix should have been made.

When the anglemen do not have easy access to the boat sheet, it is advisable to make a rough shoreline tracing showing the location, name, and brief description of each signal in the vicinity. This enables the anglemen to select strong fixes and positively identify the stations used.

5–40 Special problems in sextant fixes.—Sextant fixes at distances approaching the limit of visibility of the signals are likely to be weak because the angles are small. In such cases the angles change slowly and a slight error in the angle affects the position by a comparatively large amount. When signals are some distance away or are difficult to reflect, a telescope should always be used in the sextant, the sextants should be in perfect adjustment, and the angles should be measured and read accurately (see 3–14).

Without a multitude of small signals it is impracticable to obtain a strong fix at the inshore end of every line, as a survey vessel close to the shore is nearly on line with the signals (see 4–28). The sum of the two angles will approach 180° with one angle being very large and the other very small. The angles change very rapidly when the vessel is moving, and unusual care must be taken to mark them simultaneously. The effects of errors introduced by failure to mark angles simultaneously is minimized when the signals used are at short distances from the observer.

At times when it is impossible to obtain a three-point fix, it may be possible to measure two angles to four signals so as to fix the position. This is known as a "split fix" because there is no common center object. A split fix may occasionally be observed by accident. If the signals are appropriately located so that the loci of the angles intersect at an angle greater than 45°, the fix is just as strong as a three-point fix, but considerably more time is required to plot it. The locus of each angle must be plotted separately, the position being at the intersection of the two loci. Such a fix should be taken intentionally only when no satisfactory three-point fix is available.

5–41 Position fixing by Shoran.—The Shoran system used for control of hydrography is described in Chapter 3, Sections 33 to 47 inclusive. The system was first used in hydrographic surveying in 1945 on the ship EXPLORER in the Aleutian Islands, and has been widely used in all areas since then. The Shoran equipment is designed to measure two distances simultaneously between a mobile station and two fixed stations whose positions are known. The position of the mobile station is determined by

the intersection of two arcs centered on the known points with radii equal to the measured distances. Data for plotting a position is read directly from dials to 0.001 statute mile.

When properly adjusted and operated, Shoran provides very good control for surveys at scales of 1:20,000 and smaller. For work at larger scales it is necessary to be more careful in calibrating the equipment and to make frequent checks on the accuracy of the data it furnishes.

5–42 Zero set and zero check.—Zero set is an adjustment of a reference pulse marker (see 3–43) and zero check is a procedure for observing the stability of zero set (see 3–44). The zero set is adjusted during the calibration procedure to provide a minimum correction to observed distances. Any departure from the original setting as shown by periodic zero checks represents an additional correction to be applied to measured distances. Ordinarily these corrections are small and can be ignored for boat sheet plotting. If the range of the zero check corrections does not exceed .005 statute mile, the zero checks can be meaned, or ignored if the correction is not plottable at the scale of the survey.

If successive checks show a radical change, 0.010 statute mile or more, the cause should be determined and corrective measures taken. Such a change may be caused by loose antenna connections.

5–43 Reliability of Shoran.—There are times when Shoran distance measurements are inaccurate although the equipment seems to be functioning properly. The hydrographer must be constantly alert to detect indications of errors in the Shoran. A summary of the precautions to be used is contained in 3–47.

One of the major problems in verification of Shoran controlled surveys is encountered at junctions of adjacent surveys or at junctions of surveys by two or more vessels on the same survey sheet. Calibration corrections should be applied when plotting positions on the boat sheet in order that junctions with other surveys can be properly evaluated. Any discrepancies must be resolved in the field. A three-point fix should be observed occasionally for comparison with a Shoran fix. It is obvious that when the distance arcs intersect at an acute angle, small errors in the distances produce a larger displacement of positions than will occur when the arcs intersect at an angle of about 90°. Comparison fixes are desirable in all areas of the survey.

5–44 Shoran control procedure.—The procedure to be followed in matching pulses and reading Shoran distances is described in the Shoran manual and will not be repeated here. When Shoran is used to control a hydrographic survey, there is a sequence of events which should be followed for best results.

The entire system, both ship and ground stations, should be started at least 30 minutes before operations begin. Check and record the zero setting. Check the ship station oscillator with the ground station and, if necessary, make the adjustment for calibration synchronization (cal sync).

If circumstances permit, a series of calibration comparisons should be made (see 3–38 to 40) before surveys are begun. A preliminary table of corrections versus distance should be compiled for each shore station and posted at the plotting table. A zero check reading shall be recorded at each series of calibrations and once each hour while hydrography is in progress.

The Shoran readings at each fix shall be recorded in the sounding record, Form 275, and on the Shoran plotting abstract, Form 817. The observed distances shall be corrected on the abstract in accordance with the posted table before the positions are plotted on the boat sheet. The dials on the Shoran Indicator should not be turned until the position has been plotted and accepted as satisfactory. Occasional errors in reading the dials, or errors in recording the data can be corrected at once if the dials have not been moved.

When sounding lines are being run along preselected Shoran distance arcs, frequent

changes of course are required, the frequency and amount of change depending on the radius of the arc being followed. It is possible to follow the curve very closely; however, there will usually be periods when the vessel is slightly off the desired course. The courses need not be recorded for launch hydrography but should be recorded for ship hydrography.

5–45 **Position fixing by EPI.**—The EPI system (see 3–23 to 32) is generally used to control small scale offshore hydrographic surveys. The position of the survey ship is determined by measuring electronically the distance to two fixed stations ashore. Distances are measured in units of microseconds (one microsecond =149.8447 m). The system does not provide the accuracy of Shoran or Raydist; however, it will provide satisfactory control for surveys plotted at a scale of 1:100,000 or smaller if the equipment is properly installed, adjusted and operated. The operators at the shore stations must perform their specified duties with great care or the position data will be inaccurate. The plotted position should always be compared with the dead reckoning position, and, if there is much difference between them another fix should be observed and plotted. It is necessary to reject one or both distances occasionally on the basis of a reasonable evaluation of the dead reckoning and a series of fixes.

5–46 **EPI control procedure.**—Chapter 3 of the EPI Manual describes in detail the operation of obtaining an EPI fix. The interval between fixes depends on the scale of the survey and the speed of the ship and usually varies from 10 to 30 minutes.

Since the use of EPI is restricted to control of small scale surveys in offshore areas, the boat-smooth sheet method of plotting the survey should be used in most cases (see 5–5). The calibration program described in 3–29 and in the EPI Manual must be carried out before hydrography is begun and repeated as necessary. The effect of the ship's heading should be determined (see 3–30) and a table of corrections compiled and checked. A new table of corrections may be required as a result of subsequent calibrations. Calibrations obtained on different dates should not be meaned.

When a fix is taken the EPI readings shall be recorded in the sounding record and on the abstract (Form 817). The observed distances are corrected on the abstract in accordance with the correction table and the position plotted. The EPI dials should not be moved until the position has been plotted and accepted. The abstracts and tables of corrections shall be submitted with the other survey records for the sheet.

5–47 **Position fixing by Raydist.**—The DM Raydist system (see 3–48 to 61) is completely automatic. Once the phasemeter dials have been correctly set at a known position, the movements of the vessel are recorded on the brush recorder and shown on the dials. A fix may be obtained at any instant by reading the lane count from the phasemeter dials. Errors in measured distances may be introduced by radio interference, sky wave contamination, loss of power, or electrical storms. It is therefore essential that the brush recorder be under continuous observation to detect any gain or loss of lanes. These changes will occur in whole units and, if conditions are not too severe, the readings can be corrected. If the lane count is lost or is uncertain, it is necessary to set the dials again at a known position or calibration point.

Raydist may be used to control surveys at any scale; however, when plotting on a scale larger than 1:20,000, there are a few small corrections to be applied as described in 3–56.

The position of the sounding vessel is determined by the intersection of two distance arcs expressed in terms of lanes. The width of a lane is a function of the radio frequency used in the system.

5–48 **Raydist control procedure.**—A system of parallel straight sounding lines may be run, or a system of curved lines along selected distance arcs may be run as with Shoran. In either case fixed positions shall

be recorded at regular intervals. If a printer is incorporated in the system, the recorder simply presses a button and the lane count at that instant is printed on a paper tape and a fix mark is drawn on the fathogram. The printed numbers are copied in the sounding record and read off to the plotter who records them on the plotting abstract, Form 817. Each position number is marked on the printed tape record for easy identification.

If a printer is not used with the Raydist, two observers may be required to read the phasemeter dials at the mark. When the vessel is proceeding at full speed it is almost impossible for one person to read both dials correctly unless the sounding line is tangent to one distance arc.

The brush recorder automatically records the changing lanes (Fig. 20). As a guard against loss of the lane count, one man is stationed at this recorder and makes frequent comparison between it and the phasemeter dials. The lane count is marked on the graph at regular intervals, usually in units of 5 or 10 lanes. Unless the graph is needed to support lane count corrections, it may be discarded at the end of the day.

5–49 The operation of position fixing.—The detailed operations of position fixing varies with the method of control being used; but the general procedure is the same regardless of the method of control. All operations are carefully related in time, and certain operations must be performed by various individuals at the same instant. The recorder signals that the time for a fix is approaching, gives a second warning a few seconds before the fix, and signals the time for the fix. If all members of the party are in close contact, all of the above may be done orally, otherwise an electric buzzer or bell may be used to give the signals.

(a) **Sextant fix.**—When sextant angles are used to control the hydrography, the operation of taking a fix is generally as follows. At the last sounding before the fix the recorder calls, "On the next!" If the interval between soundings is very short, or if signals are faint, more time may be allowed by calling, "One minute!" or "Two to go!" About 10 seconds before time for the fix the recorder calls, "Stand by!" and at the exact clock time for the fix he calls, "Mark!" The anglemen should keep the angles correctly measured from the last warning until the mark and should not change the angle thereafter until the fix has been plotted. At the mark, the echo sounder operator makes a fix mark on the fathogram and reads the sounding. The left angleman calls out his angle first and then the right angleman calls his angle. The plotter or left angleman gives the names of the signals used in the fix. The recorder must repeat all data as he records them (see 5–54).

(b) **EPI or Shoran fix.**—The procedure for observing an EPI or a Shoran fix is quite similar. A minimum of one minute is usually required for observing an EPI fix, but a Shoran fix can be observed in a few seconds. The recorder issues a first warning of "One minute to go!" or "On the next!" The operator matches the pips in the scope and keeps them matched from the call of "Stand by!" until the mark. The distance readings are called out for each station and repeated by the recorder as he enters them in the sounding record. The dials should not be disturbed until the position has been plotted. The echo sounder operator marks the position on the fathogram and reads the sounding.

(c) **Raydist fix.**—Since Raydist shows the position data continuously, the lengthy stand-by period is not necessary. The recorder notifies the plotter that a fix will be taken at the end of the next sounding interval, pushes the marker button at the proper time, transcribes the printed dial readings to the sounding record at the same time calling them out to the officer in charge. If a printer is not used, a 10-second warning is given and, at the mark, the person monitoring the brush recorder reads one dial, a second man reads the other dial, and the echo sounder operator marks the fathogram.

5–50 Plotting positions.—Three-point fixes are plotted with a three-armed protractor (see 3–16) or by use of circles of equal angle (see 5–13). Plastic protractors

are used for boat sheet plotting within the limits imposed by the length of the arms. The plotting is done very rapidly so that the course may be adjusted as required to follow the prescribed line. However, the positions should be plotted as accurately as time and circumstances permit. If it is anticipated that the smooth plotting will be done by the film positive transfer method (see 6–47) the boat sheet positions must be plotted accurately.

The hydrographer usually estimates where he will be at the next fix on the basis of his course and the distance run during the time between fixes. This will assist in plotting the fix, since he can center the protractor at the estimated position, and if there is an appreciable difference between the estimated and plotted positions, the fact is immediately apparent. If the distance between plotted positions is correct, but the last position is slightly off the proposed line, a change of course is indicated. If the distance between positions is significantly different, or if the last position falls far off course it is probable that the position was incorrectly plotted or the position data are incorrect. The plotter should immediately request the anglemen to verify the sextant readings and the objects used in the fix at the same time checking to see that he has correctly laid off the angles on the protractor. If no errors are discovered the fix should be questioned in the record book and another fix observed as soon as possible. At the end of the day each questioned or doubtful fix must be examined and a decision reached as to its accuracy. The final action taken shall be noted in the record book over the initials of the hydrographer. Jumps in the line which are not otherwise explained are probably caused by an incorrectly located signal.

When electronic distance measuring devices are used to control hydrography, distance circles are drawn on the sheet (see 5–11) and positions are plotted by an Odessey protractor (see 3–22). The protractor is placed on the sheet so that its center marks the increment or decrement from the nearest distance circle for one station, the partial distance being measured by the closely spaced concentric circles. The interpolated concentric circle on the protractor will be tangent to the distance circle on the sheet. The protractor is then moved until the center marks the measured distance from the second station while keeping it in its correct relationship to the first distance circle. The position is then pricked by a needle through a small hole at the center of the protractor. Questionable position data must be treated in the same manner as that prescribed for doubtful sextant fixes.

5–51 Supervision by the Chief of Party.—The number of men required to operate a survey unit varies with the size of the vessel, area of operation and type of control being used. On a large survey ship engaged in surveys on a 24-hour basis at least three watches are required, while a launch party normally has a complement just adequate for operations during an 8-hour day.

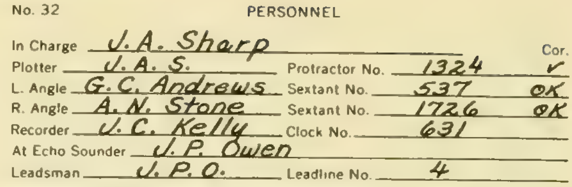
The Commanding Officer, or Chief of Party, is responsible for all the work being done by the party. He plans the work and supervises all operations. He must inspect the boat sheets and records daily, if possible, to assure himself that the work is being accomplished in accordance with the instructions, that it is complete, that the data are clearly and correctly recorded, that all indications of shoals are examined, and that all navigable channels are developed (see 1–43). From this daily examination of the boat sheet, the Chief of Party indicates to the hydrographer any additional sounding lines to be run or what practices and procedures are sub-standard, if there are any. A final examination of the completed boat sheet must be made before leaving the working ground to ensure the adequacy and completeness of the survey.

The Chief of Party need not sign the sounding records, but in his final approval of the survey he shall state the amount of his personal supervision given to the field and office work (see 7–11).

5–52 Officer-in-charge.—The officer-in-

charge of a watch aboard ship or of a launch hydrographic party is responsible for the adequacy of the survey operations and the safety of the vessel. He issues all necessary orders, supervises, and inspects the work of the other members of the survey party.

It is customary for the officer-in-charge to plot the positions on the boat sheet, issue orders to the helmsman, determine the intervals between soundings and positions, and select the objects to which sextant angles are to be taken. He may observe one of the angles, preferably the left. Junior officers assigned to the watch or party should be trained in all phases of the operation including position plotting. There may be some confusion and loss of time while young officers learn these various duties, but the training of junior officers is one of the primary duties of senior officers and must not be neglected.


No. 32 PERSONNEL

In Charge J. A. Sharp — Cor.
Plotter J. A. S. — Protractor No. 1324 ✓
L. Angle G. C. Andrews — Sextant No. 537 OK
R. Angle A. N. Stone — Sextant No. 1726 OK
Recorder J. C. Kelly — Clock No. 631
At Echo Sounder J. P. Owen
Leadsman J. P. O. — Leadline No. 4

FIGURE 56.—Personnel stamp for sextant controlled hydrography.

5–53 Anglemen and Shoran observers.—The anglemen observe the sextant angles for the fixed positions in three-point fix control. One officer may observe the left angle and plot positions; however, when qualified observers are available, it is better to have two anglemen so that the plotter may devote more time to supervision of other operations. When signals are distant or faint, or if fixes are required at very short intervals, two anglemen in addition to the officer-in-charge are necessary. One angleman should be a junior officer or a petty officer, and the other may be any member of the complement who has been trained to use a sextant. Both anglemen should act as lookouts when not taking an angle. They should report the presence of kelp, current streaks or eddies, breakers, buoys, rocks, etc. The left angleman may select the objects to be used in the fix. One angleman assists the coxswain to lower and raise the bar when bar checks are being made by a launch.

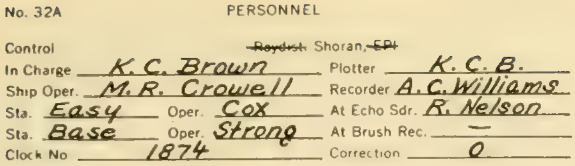
When Shoran is used for control of the hydrography, one observer is required to attend the instrument and measure the Shoran distances. If the sounding lines are being run along distance arcs, he issues orders for changes of course to maintain the required spacing. This duty should be shared by two observers alternately standing a watch of one to two hours at the Shoran indicator. When qualified, they should give occasional temporary relief to the recorder or echo sounder observer (see 2–18).

5–54 Recorder.—A competent recorder must be thorough, conscientious, accurate, and not easily rattled by confusion occasionally arising from a rapid series of events which must be recorded, and he must be familiar with the requirements of pertinent parts of this manual.

The official written record and notes of the hydrographic survey are kept by the recorder. He records the soundings as reported by the echo sounder operator, the sextant angles or other control data, and the times of these events. He also records changes of course, except when following distance arcs, and records pertinent notes in the remarks column, such as changes in speed; the beginning and ending of lines; references to adjacent features as rocks, breakers, or aids to navigation; changes in equipment or personnel; and other notes necessary for correct interpretation of the survey data. All entries must be clearly legible.

After the regular intervals between soundings and positions have been ordered, the recorder is the one who sees to it that the soundings and positions are taken at the specified times. The recorder repeats aloud all data which are called out to him to be recorded.

The recorder, with the assistance of another member of the hydrographic party, shall verify the length and markings on the lines attached to the bar check at least once each week and enter the results in the sounding record (see 3–109). On days when a


No. 32A PERSONNEL

Control ~~Raydist~~ Shoran, ~~EPI~~

In Charge K. C. Brown Plotter K. C. B.

Ship Oper. M. R. Crowell Recorder A. C. Williams

Sta. Easy Oper. Cox At Echo Sdr. R. Nelson

Sta. Base Oper. Strong At Brush Rec. —

Clock No 1874 Correction 0

FIGURE 57.—Personnel stamp for electronic controlled hydrography.

leadline is used, it shall also be compared with a standard and the results recorded (see 3–65).

It is the recorder's duty to see that the data are obtained and recorded in the various standard rubber stamps at the beginning and ending of each day's hydrography.

5–55 **Echo sounder operator.**—The duties of recorder and echo sounder operator may occasionally be combined in ship hydrography when sounding in deep water and the intervals between soundings or positions are not too short. Better results are obtained when the echo sounder operator has no other duties, and these duties shall not be combined in launch hydrography.

The echo sounder operator must be familiar with the minor adjustments to the sounder and be able to recognize faulty operation of the equipment. On portable sounders he shall maintain the initial setting at its correct position, continuously watch the frequency meter or tachometer and make any adjustments required to maintain correct motor speed. Adjustment of the initial setting on the EDO–185 shall be made by a qualified technician.

While hydrography is in progress the operator shall call out the sounding at the specified sounding interval and in addition shall report the soundings on peaks or in valleys which fall between the regular soundings. When the depth decreases rapidly to a point where danger of grounding seems evident, he shall report the fact to the officer-in-charge.

At each fixed position on the sounding line, the operator shall scribe a fix mark on the fathogram and number it for identification. Position numbers shall be verified by comparison with the sounding record and the boat sheet at frequent intervals.

Fathograms for portable echo sounders provide a printed overlap of successive scales or phases. As depth increases or decreases, the operator should make appropriate changes of scale about midway in the overlap of the scales and report the change to the recorder. The scale being used shall be marked on the fathogram except when the first phase is used. When sounding on any scale other than the first, the sounder should be turned back to the first scale at convenient times to check the initial setting.

5–56 **Coxswain.**—The helmsman on a ship or the coxswain on a launch steers the vessel in accordance with orders from the officer-in-charge or from the Shoran observer. If the launch controls are in the cockpit, the launch engineer may perform the duties of coxswain. In addition to steering the prescribed courses the coxswain acts as a lookout when he can do so.

When visual fix control is used, the coxswain should be trained to keep the launch on a range and to select new ranges for steering on adjacent lines.

5–57 **Rotation of personnel.**—Each operation in hydrographic surveying requires some training and aptitude. Some of these operations are often monotonous and may produce eye-strain or other types of fatigue if continued over a long period without relief. It is advisable that each member of the party be trained to perform at least two of the survey operations, more if possible. Rotation from one job to another during the day will create more interest in the work and reduce the strain and discomfort of continuous repetition of the same operation. There may be some loss of efficiency during the training period, but the results are well worth the effort. The program will also provide trained replacements in the event of sickness or separation of personnel (see 2–18).

5–58 **Beginning the survey.**—When the control has been established, the boat sheet prepared and all necessary data plotted

thereon, the hydrographer is ready to begin the survey. If it is proposed to run parallel straight sounding lines, a series of proposed lines are lightly penciled on the sheet. The line spacing should be slightly less than the maximum spacing authorized for the depth or area. The survey should generally begin at a junction with a prior survey and progress in a direction specified for advance in the project instructions. However, it may be desirable to survey an anchorage first, or the selection of the working area may be governed by conditions of weather and sea.

To start a sounding line the ship or launch is navigated to the beginning of the proposed line, trial positions being plotted as this point is approached. When this point is reached, the vessel is turned to the approximate course. The helmsman is told what course to steer, the recorder is told when to take the first position and sounding, and anglemen are told what objects are to be used in the fix. The first position is taken and plotted and the course is altered if necessary to follow the proposed line. Positions are taken and plotted at short intervals until a course is established which closely follows the proposed line. The time between positions can then be lengthened to the maximum permissible for the scale of the survey and speed of the vessel (see 5–36).

On approach to the inshore end of a line it may be necessary to reduce the speed of the launch. A fix should be taken at the time the speed is changed. Also when a launch begins a line near the beach from a stand-still, the fact shall be noted in the record and the next fix should be taken as soon as possible after the launch attains sounding speed.

5–59 Following proposed lines.—In hydrography, an effort should always be made to follow the proposed lines as indicated on the boat sheet. If Shoran or Raydist is being used, this is most easily accomplished by running along distance arcs from one of the stations. Any desired line spacing can be used by maintaining a constant distance from a station. This method is especially efficient when strong or erratic currents make it difficult to run straight lines.

When sextant angle control is used, the coxswain should be trained to select and run ranges as an aid to keeping on the proposed line. Otherwise, the vessel is kept as close to the line as possible by steering compass courses, making small changes as required. Considerable experience is required to gain the knack of making course changes of sufficient amounts and at the correct time. Changes in the direction or strength of the current are often indicated by "current streaks." These should be observed and reported by the coxswain or anglemen. Changes in the strength of the current may be expected in the vicinity of shoals and banks in offshore areas.

The line spacing is directly related to the depth of water, becoming wider as depth increases. The project instructions usually specify maximum spacing for a certain depth range, as 200 meters from 20 to 30 fathoms, and 400 meters from 30 to 50 fathoms. When the maximum spacing is exceeded, a split should be run to fill the void, except that a wide spacing at the outer limit of the depth range may be accepted on even slopes. The hydrographer must use good judgment in running splits and should base his decision on the character of the bottom as well as the distance between lines.

5–60 Turns and changes in course.—The soundings should be plotted as nearly as possible on the exact path of the vessel (see 5–62). When a change of course greater than 10° is made, a fix should be taken as soon as the new course is reached. When a change of approximately 90° is made the soundings on the turn may be plotted or omitted at the discretion of the hydrographer, but it is best to omit them. A fix must be taken as soon as the vessel is on the new course. Soundings shall not be recorded on the turns when a vessel turns about to begin another line.

5–61 Sounding speed.—When echo sounders are used, soundings can be obtained while the survey vessel is operated at stand-

ard speed, except when the vessel is heading into heavy seas thus creating turbulence which blocks the echo. This is the most efficient speed, since more sounding lines can be run in a specified time, and better steering control is attained than at slow speed.

The speed of advance must be reduced (a) when there is risk of grounding; (b) when the existence of submerged dangers is suspected; (c) when conditions of the sea require it; (d) when necessary to comply with specifications for minimum distance between successive positions; and (e) when sounding with leadline or pole in order that true vertical measurements can be obtained (see 3–69).

The speed should be as uniform as possible between positions. Each change of speed shall be recorded at the time of change. A position should be obtained at the time of change in speed, or as soon thereafter as practicable.

5–62 Plotting a sounding line.—After a position has been plotted, a pencil line is drawn to it from the last position. If a change of course has been made between the positions, the line should be drawn to show the course change and shall represent, as nearly as possible, the actual track of the vessel. The curved lines following distance arcs may be drawn by use of a French curve, or by use of small pieces of clear plastic trimmed to fit arcs of various radii.

When a line is run parallel with the beach, it is often impossible to obtain positions with sufficient frequency to plot all changes of course and the hydrographer should draw a line which closely approximates the path of the launch between successive positions. A note should be made in the sounding record that the boat sheet plotting shall be used as a guide in smooth plotting the line. A similar situation often exists when sounding in narrow winding channels in streams and mud flats and should be treated in the same manner.

When hydrography is done by a ship it is usually possible to ink the position numbers as soon as they are plotted, and, in some cases, the soundings may also be inked from carbon copies of the sounding record pages. In launch hydrography this is seldom possible. The positions are numbered in pencil as they are plotted, and inked in assigned color at the end of the day. In so far as it is possible to do so, the position numbers shall be placed below and to the right of the position. The numbers should be much smaller than the soundings. The day letter (see 5–35) shall be shown at the beginning and ending of each line and at every position which is a multiple of 5. The day letter shall also be shown at every detached position.

5–63 Inking soundings on boat sheet.—Soundings shall be plotted on the boat sheet in black India ink each day as hydrography progresses. The soundings shall be reduced to the tidal datum adopted for the area from predicted or observed tides. Significant corrections for phase differences or variation of the initial should be applied; small corrections can be ignored for boat sheet plotting.

The soundings between positions shall be properly located by the use of a spacing divider, and odd interval soundings correctly shown. If the film positive method of smooth plotting the survey is to be used, the sounding on the position should be omitted provided that it is not critical. In any case, the sounding must not obscure the position dot or the position number (see 6–47).

Only one unit, fathoms or feet, shall be used on the boat sheet (see 1–38). Expert penmanship is not required, but the soundings should be uniform in size and clearly legible. In congested areas a selection of soundings should be made but all soundings should be plotted which are necessary to show bottom configuration. The least depth on shoals and dangers should be shown in somewhat bolder figures than the surrounding soundings. A note should be placed in a marginal area nearby giving the least depth and a reference to the sounding record position number and day letter.

Where the depth unit is fathoms, and the bottom is generally flat or has a gentle slope, the soundings shall be plotted in fathoms and decimals in depths less than 11 fathoms.

In other areas the soundings shall be plotted in whole units (see 6–55).

5–64 Depth curves on boat sheets.—Depth curves are indispensable for interpreting and examining a hydrographic survey. There is no better gage of its completeness, adequacy, and accuracy than the ability to draw closely spaced depth curves with an assurance that the submarine relief is accurately depicted. The depth curves should be drawn on the boat sheet by the hydrographer as the work progresses, and a careful interpretation of the data will disclose where the lines have not been spaced closely enough, where additional development is required, and where errors have been made which require investigation (see 1–41).

An adequate representation of the submarine relief by depth curves is a problem similar to the representation of land topography by contours, except that the topographer has the opportunity to examine visually the topography of the area whereas the hydrographer has only the measured depths as his guide. The hydrographer should make a study of the characteristic bottom forms, as such forms usually repeat themselves in the same region and in similar regions.

Abnormal or improbable depth curves are strong evidence of inaccuracies, inadequacies, or possible errors in the hydrographic survey or the inking of the soundings, and where they result from the data, the soundings and positions should be carefully scrutinized. On extensive coastal shelves, such as exist on the Atlantic and Gulf Coasts of the United States, the depth curves are generally smooth and regular because the bottom forms are the results of wave or tidal current action on the loose materials generally found on the bottom. On the continental slopes, however, in depths greater than about 100 fathoms, the bottom forms are generally similar to those found on land. In general, an interval of 25 fathoms between depth curves is adequate for the continental slopes and the deeper waters off the Pacific and Alaska Coasts.

To draw closely spaced depth curves carefully and accurately requires the inspection and consideration of each sounding not only once but often several times, whereas in sketching widely spaced depth curves many of the intermediate soundings may not be considered at all and important indications may be overlooked (see 6–63). Where interpretation is difficult, it is often helpful to draw additional depth curves in pencil and leave these curves uninked.

In this respect some topographic experiences is a great asset as is also the ability to recognize predominating physiographic shapes from preliminary sketched depth curves. The ability to represent submarine relief by means of depth curves is acquired only by intensive training and practice and by study of similar work which has been done by an experienced hydrographer.

Depth curves cannot cross or run abruptly into each other. On approaching one another they tend toward parallelism. In general, the information from sounding lines should be sufficient to permit the delineation of continuous curves. Special care must be exercised to avoid excessive spacing of the sounding lines where their direction is parallel to the depth curves.

5–65 Depth-curve interval.—No single requirement for the spacing of depth curves can be prescribed to apply to all regions. In an area of steep slopes and irregular submarine relief it is considered sound practice to draw all the curves that the scale of the boat sheet will permit. Such close spacing of depth curves is obviously not required in areas of gently sloping bottom with practically no irregularities. A good general rule is that depth curves should be drawn according to the following intervals:

At 1-fathom intervals to 10 fathoms.

At 5-fathom intervals in depths between 10 and 50 fathoms.

At 10-fathom intervals in depths between 50 and 100 fathoms.

At 25-fathom intervals in depths greater than 100 fathoms.

The depth curves should be drawn first in pencil. The standard depth curves listed in Table 3 shall be inked in the colors specified.

Supplemental curves listed in Table 4 may be inked at the discretion of the hydrographer. If still more curves seem necessary to display the bottom configuration they may be shown with brown ink (see 1–41).

5–66 Inspection of the boat sheet.—After the proposed system of lines has been run in an area and the soundings inked on the boat sheet, the results should be carefully studied for indications of submerged features which should be more closely examined. The fathogram should be in view while this study is being made, as side echoes are important indications of shoaler depths. The study of the boat sheet will reveal where additional lines must be run in order to comply with line spacing requirements and for more adequate delineation of depth curves. Critical depths which have been transferred to the boat sheet from the chart or previous surveys must be compared with the new hydrography (see 5–15). Additional soundings may be required to prove or disprove the existence of the feature.

It is good practice to run splits and make detailed examinations of shoal indications as soon as possible after it has been determined that they are necessary. It is especially important that the surveys should be complete in any area as the end of the season is approached.

5–67 Verification of alongshore and offshore details.—The hydrographic party is responsible for the correctness of the topographic detail falling within the limits of the hydrographic survey, including the low-water line and waterfront details if the survey is carried close thereto. See Section 915, Topographic Manual, Part II. Whether the along-shore and offshore details originate with planetable or photogrammetric surveys, the information shall be verified while hydrography is in progress. Offshore rocks and other detail transferred from photogrammetric manuscripts and shown in blue (see 5–14) should be inked in black as each feature is verified as to position and character.

It is important that sufficient information be obtained to permit correction of the manuscripts where necessary and to permit the smooth plotter to reconcile any differences between positions of features shown on manuscripts and the boat sheet. If adequate information is not furnished, it is frequently difficult in later processing to determine whether there is one rock with a different position on the boat sheet and the manuscript, or whether the positions are for different rocks (see 6–89). Manuscripts compiled without the benefit of field inspection may show offshore rocks which do not exist. The existance or nonexistance of such features must be proved and clearly recorded. Corrections of all topographic detail shall be shown on the boat sheet in red with appropriate notes explaining methods used to determine the corrections.

Each isolated bare rock and rock awash in the project area must be located and its height determined by the hydrographer, except that, when the rocks on or near the high water line have been located by a topographer or on photographs during field inspection, the hydrographer must verify the data. The important rocks of a group or rocky area should likewise be located and elevations determined.

Where it is practicable to land on such features the location should be determined by a strong three-point fix and check angle taken at the rock. Otherwise the rock may be located by a minimum of three cuts from stations ashore or afloat giving a strong intersection at the rock, or by sextant positions taken at the boat with the rock in range with control stations bearing in several directions.

The height of the rock should be determined as accurately as practicable and the time of observation noted. If a landing can be made and the sea is calm, the height of a rock can be measured on a staff whose lower end is held at the water's edge, the height being noted on the staff by lining it in with the horizon with eye at the top of the rock. If it is not practicable to land on the rock, the height must be estimated as accurately as possible from a position nearby.

Where a rock has been adequately located

by the photogrammetrist or topographer and is passed on a sounding line, a note of this fact shall be entered in the remarks column of the sounding record with an estimated distance when the rock is abeam. It should be made clear that these data are not to be used to locate the rock but merely as a verification of its existence.

If bare rocks or rocks awash shown on prior surveys or on published charts are found to be nonexistent, or in different locations, or with different elevations, a full explanation shall be included in the descriptive report, with a recommendation as to the charting procedure to be followed.

5–68 Indications of shoals and dangers.—There are several sources of evidence that a shoal or submerged danger exists in the area being surveyed and the hydrographer should avail himself of all of them. This information may be obtained from:

(a) A study of soundings obtained during the systematic survey.

(b) Reports of dangers submitted by pilots, fishermen, and yachtsmen.

(c) Sighting of breakers, kelp, or other visible evidence while sounding.

(d) An examination of aerial photographs, particularly color photographs, which often reveal the location of shoals or rocks.

The spacing of the systematic sounding lines is designed to provide at least an indication of the dangers and shoals within the area. Such an indication will occur as a break in the continuity of the slope of the bottom. A more positive evidence of the existence of a shoal is found where two adjacent lines of soundings contain similar indications. Even a slight change from the average depth should be regarded as a possible indication of a shoal. In many localities it is out of the question to examine every such indication, nor is this required. The hydrographer must decide which areas shall be further developed, and the Chief of Party must make a final inspection of the work to assure himself that no additional development is required. In deciding which indications should be developed, the hydrographer should be guided by the considerations listed in 1–27 and his past experience in similar areas.

In all project areas, pilots, fishermen, yachtsmen, and others with local knowledge should be consulted freely for the purpose of collecting hydrographic information, and all reports of rocks, shoals, or obstructions must be investigated. An attempt should be made to verify the information from several sources. If it is not practicable to get someone to guide the hydrographer to the uncharted feature, an approximate location should be obtained and plotted on the boat sheet. It is sometimes difficult to obtain exact information on the location of rocks or shoals, and an extensive examination may be required to find them.

All members of a hydrographic survey party, when not otherwise engaged, should be alert to detect visible evidences of submerged dangers. In tropical waters coral banks and shoals are visible for a considerable distance when the sea is calm, the observer is stationed well above the water, and the sun is high and at the observer's back. A breaker is clear evidence of an obstruction or shoal, but a current eddy indicating a shoal is less apparent and may not be detected. The eddy is caused by the current being disturbed in its progress by a shoal. The eddy will always be seen downstream from an isolated shoal, the distance depending on the depth of the water and the velocity of the current. Likewise, eddies are more marked when the difference in depth between the shoal and surrounding bottom increases. The eddies are most noticeable at the last of the ebb or first of the flood tide.

In areas where kelp grows it is one of the best indications of dangers because it is generally associated with rocky bottom. Each isolated growth of kelp must be investigated. In addition to the usual data a statement should be made in the record as to the value of the kelp for marking the spot; whether it is visible at all stages of the tide or whether it tows under so as to be nearly invisible at times.

5–69 Development and examination of shoals.—When it has been determined that

shoal indications exist which require further investigation, the limits of the area must be defined by running a series of closely spaced sounding lines. A study of the soundings thus obtained should reveal the approximate location of the least depth, but may not establish the least depth on the feature. A more intensive examination of the shoalest part of the feature should be made in an effort to obtain the least depth. When the bottom is visible, this is an easy task since a lead can be placed on the top of all high points and the depth and position of each one recorded. In other areas the problem is more difficult. It is best to use a short wire drag, if this is possible with the available equipment. Otherwise, a small buoy should be anchored near the place where the least depth is suspected to exist. The buoy will serve as a reference point while the launch cruises slowly over the area. A second marker buoy may be used to mark the shoalest sounding obtained by the echo sounder. The final examination is then made by drifting over the shoalest part taking leadline soundings. Three or four leadsmen may be distributed along the length of the boat and, as the boat drifts with the wind or current, the bottom is felt and the least depth recorded. The boat should be allowed to drift across the shoal several times, each time overlapping the previous path about half the length of the boat.

When the existence of a pinnacle rock is suspected from the general nature of the visible terrain, a very patient and exhaustive search must be made or the least depth may not be found.

5–70 Record of shoal examination.—Where a shoal is examined by sounding along a series of closely spaced lines, all data shall be recorded in the sounding record as usual (see 5–25). Where the least depth is found by drift sounding or any other nonsystematic procedure, a full report must be entered in the sounding record of the following items when they are not otherwise evident:

(a) The method of search used.

(b) The length of time spent in the examination.

(c) A statement as to whether bottom was visible or not.

(d) A brief description of the feature including character of the bottom.

(e) Whether the shoal is marked by kelp, eddies, or other visible evidence.

5–71 Detached breakers.—Where the existance of a sunken rock or other obstruction is evidenced by breakers and it is impracticable to locate it by a three-point fix or to obtain a sounding on the spot, it must be located by cuts from nearby positions of the sounding vessel. The cuts should form a good intersection, and the depth over the feature should be estimated and the time noted. The conditions under which the area breaks must be noted, at what stage of the tide, and under what conditions of sea. Where sunken rocks exist inside a generally foul area they may be symbolized without location provided the outline of the foul area is accurately located.

Whenever possible such features should be located during periods of minus tide and relatively calm sea when danger of damage to the launch is least. Small areas around rocky points can often be examined and the limits of a foul area determined in a skiff or other small boat.

5–72 Wrecks and obstructions.—All wrecks and obstructions not afloat should be located and as complete information as possible furnished. Whether the wreck is totally submerged, visible at all stages of the tide, or visible at some stage of the tide, should be stated and any visible part of the wreck should be described. Sunken wrecks should be treated as dangers or shoals (see 5–69) and the same information should be obtained relative to them. The least depth on a wreck is practically impossible to determine without dragging the area because of the probable existence of masts or other parts of the wreck which one cannot expect to find by ordinary sounding methods.

When large pieces of floating wreckage, logs, or other debris, menacing to navigation, are sighted in areas where such obstructions are not commonly encountered,

they should be reported immediately by radio to the Commander of the nearest U.S. Coast Guard District.

5–73 Discrepancies at crossings.—Crosslines are intended to disclose discrepancies in soundings resulting from various causes (see 1–26). The discrepancies may be systematic or accidental. They must be recognized as evidence of some fault of the apparatus, method, or record, requiring a study to discover the source and to indicate the most probable correction.

The allowable differences in depths at crossings in any area should be based on the amount of horizontal displacement corresponding to the differences in depth, rather than a percentage of the depth. In comparatively even bottom a difference of 2 or 3 feet may be excessive because of the lateral displacement of the depth curve. In areas of irregular bottom or on steep slopes differences of several feet or fathoms may be allowable since the depth curves will not be appreciably affected. Allowable differences at crossings on the smooth sheet are specified in 6–61(d). Since minor corrections are ignored and predicted tides are used when inking soundings on the boat sheet, greater differences may be expected. In areas of smooth bottom and depths less than 11 fathoms, the discrepancies should not exceed 2 feet or 0.4 fathom. In areas of irregular bottom and in depths greater than 11 fathoms, discrepancies should not exceed 3 percent in the lesser depths and should decrease to 1 percent or less in ocean depths.

When the discrepancy is consistent at a number of successive crossings, and the control is strong, it is probable that the echo sounder is at fault or that the plane of reference is incorrect. When Shoran control is used and a moderate displacement of the sounding line would bring the hydrography into agreement, the calibration of the Shoran should be suspect and should be repeated.

Several vertical cast comparisons must be made in the vicinity of the crossings to support the conclusions reached by a study of the recorded data (see 5–75).

5–74 Discrepancies at junctions and overlaps.—When inshore launch hydrography is overlapped by the ship at the offshore limits of the launch work, soundings at the junction sometimes fail of agreement. Since it is not practicable to obtain bar checks on a ship, reliance must be placed on vertical cast comparisons to determine the instrumental error of the echo sounders used aboard ship. Several comparisons shall be made in the overlap area to provide data for reconciliation of possible discrepancies.

A similar situation exists when the hydrography accomplished by different launches is joined on the inshore sheets. If there is a displacement of the depth curves at the junction it is probable that an error exists in the work of one or both launches and the amount and source of the error must be established by comparison of both echo sounders with vertical cast soundings.

5–75 Other discrepancies in hydrography.—On occasion other discrepancies are found which are less obvious and more difficult to explain or correct. After the regular system of lines has been run over a wide area, it is sometimes necessary to reduce the spacing at the inshore ends of the lines in order to comply with instructions. The soundings on the alternate lines may differ by two to three feet in areas of comparatively flat bottom and the soundings on one system of lines are obviously in error. In other instances the same launch has used different echo sounders on alternate days and the soundings obtained with each instrument are consistent within themselves but fail of agreement with those from the other.

In such cases, the hydrographer must make a field test to determine which soundings are in error and, if possible, determine the cause of the discrepancy and eliminate it. The source of these types of discrepancies is usually found in the echo sounder or the method of operation. On 808 type echo sounders the operator may have the initial cutout switch in the on position for operation in shoal water and the initial setting may be incorrect; or the motor speed may not be correct. The vibrating reed is subject to movement by extraneous vibrations and

may not correctly reflect the operating speed. A speed count should be made and the paper speed measured to see that it is correct. This type of echo sounder is also sensitive to changes in gain and the operator should be cautioned against using a low gain.

5–76 Character of the bottom.—In all hydrographic surveys, the character of the sea bottom shall be determined at frequent and regular intervals throughout the project area to meet the needs of navigation and for other purposes. This applies particularly to harbors and anchorages and in all depths where vessels may anchor. In addition to furnishing data for selection of an anchorage, fishermen are assisted in selecting places where fish may be found and in avoiding places where their equipment may be damaged.

A sampling of the surface layer is usually adequate to define bottom characteristics for charting. An armed lead, a small snapper cup, or a scoop fish, will furnish samples of sufficient size. Since nearly all soundings are obtained by echo sounders, it is necessary for the hydrographer to make a special effort to obtain bottom samples. In depths of 20 fathoms or less this is readily accomplished with a lead line, but in greater depths a sounding machine should be used. Whenever possible the samples in deep water should be obtained by the ship or a vessel equipped with a power driven sounding machine. Launch hydrographers are inclined to defer this operation and frequently fail to obtain as many samples as they should to adequately define the character of the bottom. The frequency of bottom sampling with respect to depth of water is specified in 1–42.

If a more detailed study of the ocean floor is contemplated, the bottom samples shall be obtained by a suitable corer or by dredging. The project instructions will specify the density of sampling required and the type or types of samplers to be used. A core sample should be preserved intact in the sleeve of the corer or be carefully extruded into a suitable container. Dredging samples should be preserved in sturdy containers. All samples shall be carefully labeled and cross referenced to detailed records of place and time of sampling.

5–77 Classification of bottom materials.—A complete description of a bottom sample consists of: one or more adjectives descriptive as to size or consistency; one or more adjectives designating color; and one or more nouns naming the class of bottom material. The descriptions should follow a standard classification and utilize standard abbreviations as shown in part "S" of Chart No. 1, Nautical Chart Symbols and Abbreviations, a part of which is shown in 5–88. Descriptive terms needed, which are not included in the chart, should be written in full. The description shall be arranged in the following order: size or consistency, color, and noun. Bottom characteristics shall be shown in black ink on the boat sheet, below and to the right of the position.

A precise classification of bottom materials in most cases would require a laboratory analysis, but this is ordinarily impracticable in most hydrographic surveying. An inspection of a sample by sight and touch will enable the hydrographer to give a reasonably accurate description of the material.

Close to shore and on the continental shelf the ocean bottom will generally consist of sands, gravels, muds, and remains of plant and animal life. Ledge rock may be exposed in a few areas close to shore where slopes are steep. Sand is generally easily recognized; even the finer grained sands feel gritty when rubbed with the finger in the palm of the hand and when dry will separate into grains visible to the naked eye.

Technically there are two classes of material finer than sand. These are silt and clay. For practical purposes these are often classified under the general term of mud. The particles are much finer than sand and do not feel gritty to the fingers. Clay is a finer grained deposit than silt and is usually sticky to the touch.

Sediments are variously typed according to the size of the particles composing them. The following tabulation will serve as a general guide for classification of the sands and coarser particles. It is not intended that the

dimensions be measured. A careful estimation by eye is satisfactory.

TABLE 10.—Sediments classified by size

Sediment		Diameter Of Grains: In millimeters	Diameter Of Grains: Approximate equivalent in inches
Ooze			
Clay, Silt	Mud	0.02–0.1	
Sand	Very fine	0.1–0.2	
	Fine	0.2–0.3	
	Medium	0.3–0.5	
	Coarse	0.5–1.0	
Gravel	Fine	1–2	1/25–1/12.
	Medium	2–4	1/12–1/6.
	Coarse	4–6	1/6–1/4.
Pebbles	Fine	6–10	1/4–2/5.
	Medium	10–20	2/5–4/5.
	Coarse	20–50	4/5–2.
Stones		50–250	2–10.
Boulders		250 upwards	10 upwards.

5–78 Description of bottom materials.— The nature of the bottom materials is indicated by an adjective, such as soft, hard, sticky, or the size, as coarse, fine, or medium. When the consistency of the bottom is determined by feeling with a leadline or pole and without a visual examination, it shall be described by an adjective unaccompanied by a noun. The use of the term "rocky" is to be avoided in this respect; the term "hard" should be used instead in all cases where applicable. The term rocky may be used when it is known that the bottom is bedrock or consists of material larger than gravel but no speciman can be obtained for examination.

The color of the specimen should always be noted while it is wet, as the color of some sediments is different when dry. The terms "dark" and "light" should never be used alone; they are intended for use in qualifying the intensity of a color.

5–79 Verification of charted features.— The data transferred to the boat sheet as specified in 5–15 must be compared with the results obtained by the survey. If the transferred sounding is obscured by the new soundings, there is a chance that it may be overlooked and not properly investigated. Each charted danger must be surveyed in detail. If the hydrographer fails to find a reported shoal or danger at its charted position, the survey of the area must be so complete that the cartographer is justified in removing the feature from the chart. All indications of shoals in the vicinity should be meticulously examined as the positions of reported dangers are often in error. A sounding or charted danger cannot be removed from the chart unless there is conclusive evidence that the feature does not exist.

It is not sufficient to merely prove the existence of charted features; their positions, the least depth on submerged features, and the elevations of the exposed ones must be determined. If the new survey finds a least depth which is greater than the charted depth, the descriptive report must explain the discrepancy and contain a positive recommendation as to which depth should be charted, and why (see 7–4).

One of the most difficult problems encountered in hydrographic surveying is concerned with charted piling. Submerged stubs of broken piles are almost impossible to locate by any means other than dragging. When there is no visible evidence of a charted pile or dolphin, the hydrographer should consult with local agencies as the Corps of Engineers, Coast Guard, or owner of the waterfront property to find out whether the piles have been removed. Lacking conclusive evidence to this effect, the area should be examined at the lowest tide, and it may be necessary to use a small drag before a definite recommendation can be made.

Where an adequate wire-drag survey has been made in a nonchangeable area, the dangers, shoals, and the least depths originating with the wire-drag survey need not be verified unless required by the project instructions. In an area of considerable importance to navigation, obstructions and dangers to navigation may have been removed. The hydrographer must consult with the Corps of Engineers to learn which obstructions have

been removed. In such cases, a new least depth on each feature so affected must be determined by hydrographic examination. Rocks and obstructions supposed to have been removed by blasting should be wire-dragged, if possible.

5–80 **Aids to navigation.**—The positions and characteristics of all aids to navigation in the project area must be accurately determined, and the dates of the determinations given. The date of location is especially important in connection with floating aids for at the time of location the aid may have been temporarily off station and subsequently replaced on its correct station by the United States Coast Guard.

All fixed aids to navigation should be located by triangulation (second or third order) if their geodetic positions are not already available or if the aid has been moved or rebuilt since the date of the previous determination (see 1–50). The aids may be located by photogrammetric methods when triangulation is impracticable or too costly, but the determinations shall be such that no appreciable error will result. In projects where there are numerous minor daybeacons whose positions are subject to frequent change, these may be located by topographic, photogrammetric, or occasionally by hydrographic methods.

The positions of all fixed aids located by the survey party shall be reported on Form 567, Landmarks for Charts. The name and description of each aid shall agree with the data published in the most recent Light List, or differences shall be explained in the report (see 7–22).

The positions of and the depths at all floating aids to navigation in the project area shall be determined during the hydrographic survey (see 1–50). A floating aid should be located by a fix at the aid, not by cuts from shore stations, and a check angle should be observed. Where a marker buoy is maintained near the aid, the positions of both shall be determined.

If a floating aid is found to be off station by an amount which makes it unsuited to mark the feature intended, the Commander of the nearest Coast Guard District should be notified at once. Any recommendations, based on the new hydrographic survey, for additional aids to navigation or for more desirable locations for existing aids, should be reported to the Coast Guard and to the Washington Office in writing and shall be accompanied by a photostat or tracing of the boat sheet.

Reference shall be made in the descriptive report to any reports which have been made to the Coast Guard relative to floating aids to navigation.

Refer to 2–48 for instructions on preparation of a special chart to be furnished the Coast Guard for use in locating floating aids to navigation.

The azimuth of all light and daybeacon ranges maintained by the Coast Guard for use in navigation in the project area must be accurately determined. The ranges will usually be located by triangulation or photogrammetric methods. In the latter case the hydrographer should verify the azimuth of the range by observing one or more strong sextant fixes with check angles some distance away from the front range. The azimuth of a range established for use in crossing a bar shall be determined or verified by sextant fixes on or outside the bar.

5–81 **Nonfederal aids to navigation.**—Aids to navigation which are established privately or by state or local governments shall be located by the hydrographic party, and their positions shall be shown on the boat and smooth sheets. The status of these aids shall be made clear on the sheet and in the descriptive report. The report should state the purpose of each unofficial aid, the date of its establishment, the agency or person who established it, and whether it is maintained, if these facts can be ascertained.

5–82 **Bridges and cable crossings.**—Bridge and cable clearance data shown on nautical charts and in Coast Pilots are usually furnished by the Corps of Engineers, U.S. Army. Survey parties should refer to the List of Bridges over the Navigable Waters of the United States, commonly referred

to as the "Bridge Book," published by the Corps of Engineers. Field parties shall measure bridges and cables only where charted clearances are questionable, where definitive information is lacking, or where there is new construction. The district office of the Corps of Engineers should be visited, if practicable, and the charted or field clearances compared with Corps of Engineers files. Where Coast and Geodetic Survey and Corps of Engineers values differ, Corps of Engineers shall decide which value to use. See Section 3–25 of Coast Pilot Manual.

The location of bridges, overhead cables, and shore ends of submarine cables shall be determined and shown on boat sheets with descriptive notes.

5–83 Soundings at wharves and in docks.—Where there are wharves and docks within the area of a hydrographic survey, accurate sounding lines shall be run close to and along the outer faces of the wharves and in docks and slips (see 5–26). In addition to any other lines that shall be run, soundings shall be taken along the line likely to be occupied by the keels of vessels berthing there.

The soundings in the vicinity of wharves and docks should be shown on subplans at an enlarged scale wherever the scale of the regular survey of the area is too small to show the detail adequately. If the project instructions require it, or if the importance of the area warrants it, dock and slip areas shall be surveyed at a large scale using one of the control systems described in 5–126.

5–84 Sounding records.—The fathogram is the official record of the soundings when an echo sounder is used. The sounding record (Form 275) is the official record of position data and of all soundings taken by leadline, pole, or wire. Many notes containing supplemental or explanatory information are inserted in the record book. The record should be complete and self-explanatory. From it, and the fathograms, it should be possible to replot the survey at any future date. Modern survey methods are complicated and the records must be accompanied by various reports containing information

No. 45 EPI EQUIPMENT

Ship Controller-indicator No. 57-204
Ship Transmitter No. 57-77

Ground Sta.	Indicator	Transmitter
Wind	31	11
Pine	32	13

No. 104
SHORAN APPARATUS
Station Name Arch Dock
Ship Set Number 518
Shore Set Numbers 1372 825
ZERO SET 99.814 99.814

No. 50 RAYDIST EQUIPMENT
Ship Station No. 59-4
Red Station No. 59-4
Green Station No. 60-2

FIGURE 58.—Stamps used to record identifying number of electronic equipment being used.

which cannot be shown in the record books or on the smooth sheet, such as calibration data, Coast Pilot notes, and descriptive reports.

The importance of clear and comprehensive records and reports cannot be overemphasized, for the value of a survey is impaired if the records and reports are incomplete, unintelligible, or inadequate in any respect. Satisfactory records can be obtained only by the exercise of good judgment and constant attention and care on the part of all concerned.

It is incumbent on the Chief of Party to see that the records are arranged in the most convenient manner for all concerned, that *all* necessary records and reports are submitted at the proper time, and that they are appropriately cross-referenced for easy reference and complete understanding. All records and reports which pertain to one hydrographic sheet, and one only, should bear the registry number of that survey. All records and reports submitted on a seasonal or project basis, so that they are applicable to more than one hydrographic survey, should make reference to the registry numbers of all surveys to which they are applicable. The descriptive report to accompany each hydrographic survey should refer to all of the special, seasonal, or other reports and records which contain any data pertinent to the survey (see 7–4).

5–85 Form 275, Soundings.—Form 275, Soundings, is the basic record book for all

hydrographic surveys, except wire-drag surveys which are recorded in Form 411. The soundings of each hydrographic survey unit shall be recorded chronologically in a separate series of volumes for each hydrographic sheet. Under no circumstances shall hydrography which is to be plotted on two or more separate hydrographic sheets be intentionally recorded in the same volume. Sounding volumes shall be numbered consecutively as the survey progresses. If more than one hydrographic survey unit surveys in an area covered by a single sheet, a temporary series of numbers shall be used by each unit which uses more than one volume. When the survey is complete, the records for each survey unit shall be grouped in proper order, the various groups combined, and the complete set of records shall be numbered consecutively and permanently (see 1–32). The field number and registry number shall be lettered in pencil on the Title Page of each record book.

The record must be unmistakably legible. Fine lettering is not required, neither is it necessary to print in making entries, but it is essential that every numeral, abbreviation, and word be clear beyond doubt. The work must be recorded in a systematic manner and, insofar as possible, in the form prescribed in this Manual.

The record book should be protected while in use by a paper or other suitable cover. This is especially important in launch hydrography where spray, rain, or other conditions may result in damage to the records.

A sounding record is essentially a time record of a recurring series of acts and events, with occasional interspersion of related material. The record must clearly show the relationship between these acts and their recorded times. Generally, each entry should appear on the same horizontal line with its respective time, but occasionally, miscellaneous notes may be made at other places and referred to their corresponding times by distinctive reference marks. The approved manner of recording hydrography is shown in Figures 64 to 66.

While space should not be wasted in the sounding record, no attempt should be made to save it by crowding the data. It is frequently necessary to scale soundings from the fathogram at irregular intervals in order to plot bottom profiles correctly. When sounding in an area of uneven bottom, the soundings at regular intervals should be recorded on alternate lines of the record book, but when the bottom has a generally smooth and even slope a sounding may be recorded on each line.

Recorded data must never be erased, all corrections being made by crossing out the incorrect entry and making the correct one above or to one side, where it cannot be misinterpreted. This prohibition does not apply with respect to soundings scaled from a fathogram when congestion and ambiguity would result from its application. Entries which are rejected for any reason shall be indicated by an R written boldly over the entry.

Rubber stamps are provided and must be used for recording nearly all the information required at the beginning and end of the day's work and for many of the entries made during the day.

5–86 Use of abbreviations.—The principal duties of the recorder are described in 5–54. Because of the amount of recording and the speed which is often required, abbreviations for many of the terms and expressions which are used repeatedly are advantageous. The lists which appear here are to be considered standard. This does not preclude the use of common well-known abbreviations which may not be included. The recorder should know these abbreviations and use them where applicable. When it is found necessary to use unlisted abbreviations they should be listed and explained in the first volume of the sounding records.

No 33 SOUNDING APPARATUS

Echo Sdr. No. 29 Type 255-C
Calibrated Velocity 800 fms. per sec
Initial Set at 6 ft. ~~fms~~
Transducer Draft 8 ft ~~fms~~
Phase Correction A-B 0 ; B-C 0 ; C-D 0
Speed Count ___ revs ___ sec
Stylus Length Correct OK.

FIGURE 59.—Record of sounding apparatus used.

5–87 Standard abbreviations.

Abbreviation	*Term*
$<$	angle.
⊙	signal.
θθ	on range.
ah	ahead.
B.S.	boat sheet.
c/c	change course.
cor	correction.
dist.	distance.
DR	dead reckoning.
E. Sdr.	echo sounder.
fm	fathom.
F.S.	full speed.
H.L.	handlead.
H.S.	half speed.
hyd.	hydrography.
L $<$	left angle.
Lat. or ϕ	latitude.
L.B.	line begins.
L.E.	line ends.
L.L.	leadline.
Long. or λ	longitude.
LR	line resumes.
LTL	line turns left.
LTR	line turns right.
LTLA	line turns left about.
LTRA	line turns right about.
M	mined.
NP	not plotted.
obj	object.
o/c	on course.
P or PS	pole (sounding).
pgc	per gyro compass.
pos	position.
PSC	per standard compass.
P stg C	per steering compass.
R	rejected.
R $<$	right angle.
RC	revolution counter.
r.p.m.	revolutions per minute.
S	same.
sdg	sounding.
Sl. S.	slow speed.
st	stop.
stbd	starboard.
St. S.	standard speed.
T	true (bearing).
VC	vertical cast.
WD	wire drag.

5–88 Abbreviations for bottom characteristics.—The following abbreviations concerning quality of the bottom are taken from Section S of Chart No. 1, Nautical Chart Symbols and Abbreviations, December 1959 edition and shall be used to record data obtained by bottom sampling.

Abbreviation	*Term*
Grd	Ground.
S	Sand.
M	Mud; Muddy.
Oz	Ooze.
Cl	Clay.
G	Gravel.
Sn	Shingle.
P	Pebbles.
St	Stones.
Rk; rky	Rock; Rocky.
Blds	Boulders.
Qz	Quartz.
Co	Coral.
Co Hd	Coral Head.
Vol	Volcanic.
Vol Ash	Volcanic Ash.
La	Lava.
Pm	Pumice.
Cn	Cinders.
Sh	Shells.
Oys	Oysters.
Ms	Mussels.
Spg	Sponge.
Wd	Seaweed.
Grs	Grass.
Gl	Globigerina.
fne	Fine.
crs	Coarse.
sft	Soft.
hrd	Hard.
stf	Stiff.
sml	Small.
lrg	Large.
stk	Sticky.
brk	Broken.
spk	Speckled.
gty	Gritty.
fly	Flinty.
glac	Glacial.
wh	White.
bk	Black.
vi	Violet.
bu	Blue.
gn	Green.
yl	Yellow.
or	Orange.
rd	Red.
br	Brown.
ch	Chocolate.
gy	Gray.
lt	Light.
dk	Dark.

5–89 Page headings.—Appropriate entries shall be made in full at the top of the first and last record page of a day's work and, if it is divided between two volumes, on the last page of the first and the first page of the second volume. The locality, sublocality, date, and name or number of the sounding vessel can be entered with rubber stamps. The entries should be made on all pages if this does not interfere with the recording of more important data.

The assigned day letter (see 5–35) shall be entered at the top of every page in the color used to identify the work of that unit and in capital or lower case letters as appropriate.

The page headings should never be entered in advance of the hydrography.

5–90 Information at beginning of day's work.—Certain information relative to personnel engaged, instruments used and their adjustments, and other pertinent facts,

which are important to a complete record of the operation, shall be entered at the beginning of each day's work.

When the hydrography is controlled by sextant angles, the names of the personnel engaged in the surveying, and the number of the instrument used by each, shall be entered in the appropriate spaces of Stamp No. 32—Personnel (Fig. 56). The correctness of the instruments used shall be verified and that fact noted after the number of each instrument.

If the hydrography is controlled by an electronic system of positioning, Stamp No. 32A shall be used, and entries made in all appropriate spaces (Fig. 57).

When operations are on a watch basis and most of the personnel are relieved at regular intervals, Stamp No. 32 or 32A should be used to record the changes. For temporary relief, when only one person is relieved, or when two members of the group change places, the fact shall be recorded in the remarks column.

5–91 Identification of electronic equipment.—A change of a part or unit in an electronic system used to control a survey may alter the calibration of the system. Any change made at a ship or shore station must be reported and recorded at the time the change is made.

It is desirable to have a history of the performance of various types of equipment, and it may be useful at times to have a history of a specific ship or shore station set. See Chapter 3.

Stamps No. 45, 50, and 104 (Fig. 58) shall be used to identify EPI, Raydist, or Shoran ship and ground stations used to control the survey. This information shall be entered at the beginning of each day's work, and any changes which occur during the day shall be noted in the remarks column.

5–92 Sounding apparatus.—The kind and instrument number of the sounding apparatus used shall be entered in rubber Stamp No. 33 (Fig. 59) at the beginning of the day. On ships which use shoal and deep water echo sounders at various times during the day, each instrument must be identified and the source of the soundings must be shown in the remarks column when changing from one to the other. If a PDR is used, this fact should be noted immediately below the stamp.

When leadline or pole soundings are recorded, the number of the leadline shall be entered below the stamp or in the remarks column and a reference shall be made to the volume and page where the leadline comparison is recorded.

5–93 Comparison of sounding apparatus.—Any comparison of a leadline, or the lines on a bar check apparatus, made with a standard shall be recorded in the columns below Stamp No. 35 (Fig. 60). This stamp shall also be used to record echo sounder calibrations obtained by the bar check method at any time during the day's work.

Comparisons between simultaneous vertical cast and echo soundings shall be recorded under the headings of Stamp No. 43 (Fig. 61). The registering sheave or leadline number should be noted and reference made to the correction factor for the sheave or the comparison of the leadline with the standard.

Phase comparisons observed with 808 or

No. 35 BAR CHECK
~~LEADLINE COMPARISON~~

Voltmeter ______ Frequency Meter 60 cps.
Sea Smooth Wind Calm
Bar Check Results Good Fair Poor
Leadline No. ______
Latitude 41-21.7 Longitude 71-32.0

Mark or Depth Rdg. M	True Length or Depth D	Correction D-M	Gain Setting
10.2	10 ft.	-0.2	7
15.2	15 "	-0.2	7
20.2	20 "	-0.2	7
30.2	30 "	-0.2	7
40.0	40 "	0.0	8

FIGURE 60.—Record of bar check with entries properly made.

No. 43 SIMULTANEOUS COMPARISON

Vertical Cast	True Depth	Echo Sounding
63 fms	64	62.5

FIGURE 61.—Stamp used for recording simultaneous comparisons.

EDO-255 echo sounders shall be recorded on the right hand page of the sounding record as they are made.

All standardizations and comparisons recorded in a sounding volume shall be properly indexed in the front of the book for easy reference when the data are summarized at a later date.

5-94 **Preliminary run and weather.**—The time the party got underway or left headquarters and the distance in nautical miles to position 1 of the day's work shall be entered in Stamp No. 34 (Fig. 62). The state of the weather, wind and sea shall also be entered in this stamp. Any change in the weather shall be noted in the remarks column. If hydrography is continuous on a 24-hour basis, the state of the weather, wind, and sea shall be recorded at the beginning of each watch using Stamp No. 20 (Fig. 63).

Stamp No. 34 shall also be used at the end of the day to enter the distance from work and the time of arrival at the anchorage or headquarters.

5-95 **Column entries.**—Figures 64 to 66 illustrate the methods of recording data for a hydrographic survey. The pages of the sounding record are ruled into headed columns. It is important that each entry be made in the correct column and that entries do not encroach on adjacent columns. All of the data which are related to a specific time entry shall appear on the same horizontal line, except that where more than one line is required to enter the data only the first entry falls on that line. Miscellaneous entries in the remarks column may be referred to their respective times by the use of corresponding reference marks at both. Numerals should not be used for this purpose.


No. 34 Depart Arrive Distance
Anchorage 0640 Mi.
Working grounds 0750 13.4 Mi.
Underway at Weather Cloudy
Wind NE 3 Sea Lt. Chop

FIGURE 62.—Stamp No. 34 with entries properly made.

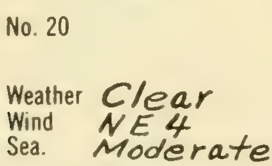

No. 20
Weather Clear
Wind NE 4
Sea. Moderate

FIGURE 63.—Facsimile of Stamp No. 20.

Positions shall be numbered consecutively starting with number 1 at the beginning of each day (see 5-34). These position numbers shall be entered in the column headed "Position Number" on the left and right-hand pages and on the same line with the time of observation. No other entries shall be made in these columns.

Standard time shall be used in all hydrographic recording and the standard meridian shall be noted at the head of the time column at the beginning of each day's work. Time shall be recorded by numbering the hours consecutively from 0 (midnight) to 23 (11 p.m.). All times shall be recorded in the "Time" column with the corresponding data to which they refer entered on the same horizontal line. The exact time of each position, each regular interval sounding, and each entry that is used in plotting, must be recorded. Soundings at peaks and deeps which are recorded between the soundings recorded at regular intervals may be timed as a fraction of the interval, as ¼, ⅓, etc., or the time may be recorded as scaled from the fathogram.

All times shall be recorded from a carefully regulated clock (see 3-110). Echo sounders are designed to operate at a constant speed, but they are not designed to measure time and shall not be used in lieu of a clock. The clock shall be set to the correct time at the beginning of the day and shall be compared with the standard at the end of the day. Any gain or loss of time shall be recorded. When survey operations involve the use of two or more clocks, as in EPI controlled surveys, the clocks shall be set correctly at the beginning of the day and verified at least once each watch throughout the day (see 3-32).

Soundings shall be entered in the double column headed "Soundings." If the bottom is generally even so that only a few soundings

Locality PACIFIC OCEAN

Date AUG 10 1959

Sublocality NORTH OF PT. SUR CALIF.

Boat used PIONEER ; *H* day

Position number	Time 120 W (h m s)	Soundings Fathoms	Soundings Tenths	Corrections: Echo Fathoms	Corrections: Tide reducer Fathoms	Corrections: Index Fathoms	Reduced soundings Field Fathoms	Reduced soundings Field Tenths	Reduced soundings Office Fathoms	Reduced soundings Office Tenths
47	10 17 00	49	0 *	+0.4	-1.6	+0.4	48	2		
	30	53	5			+0.4	52	7		
	18	76	0**	+0.4		+2.4	77	2		
	30	94	–	0	-1.6		94	8		
	19	113	–		0		115	4		
	30	135	–				137	4		
48	20	160	–			+2	162	–		
	21	206					208			
	22	258					260			
	23	310					312			
49	10 24 –	356					358			
	25	372					374			
	26	386				+2	388			
	27	410				0	410			
50	28	434					434			
	29	466		+3			469			
	45		*							
	10 30	502					505			
	31	540					548			
51	32	576		+3			579			
	33	605		+4			610			
	34	650					655			
	35	685		+4			690			

Bottom heading by Gyro compass	Position number	Position control data		Remarks
272	47	Pin	75-33	Line begins S1. S.
		Mon		φ 36 27.0
		Sur	56-12	λ 121 58.1
				*Edo 255-A Scale
				** From PDR
				Inc. Speed
	48		57 21	Std. Speed
273			42 17	
		-3.3	+4.7	
				Change to
		Ran	Gem	Raydist
	49	667.4	552.6	
		664.1	557.3	
271				
	50	684.3	562.2	
		681.0	571.9	
				*Current Streak
	51	701.5	580.8	
		698.2	585.5	

FIGURE 64.—Record of echo soundings, sextant fixes and Raydist control, showing application of rules for entering corrections. (Double page of sounding record reduced about one-half.)

need be recorded at odd intervals, a sounding may be entered on each line except the line following a position. Where the bottom is irregular and many extra soundings are scaled from the fathogram, the soundings at regular intervals shall be entered on alternate lines.

Soundings shall be entered in fathoms and decimals, or feet and decimals (see 1–38 and Table 2). No sounding shall be entered in fathoms and feet, and fractions shall not be used. The depth unit shall be indicated by a line through the inapplicable subheading at the top of the double column.

Locality S. E. ALASKA

Date AUG 10 1958

Sublocality CLARENCE STRAIT

Boat used LAUNCH 176 ; f *day*

Position Number	Time (Mer 135) h m s	Soundings Fathoms	Soundings Tenths	Corrections: Echo Fathoms	Corrections: Tide Reducer Fathoms	Corrections: Fathoms	Reduced Soundings Field Fathoms	Reduced Soundings Field Tenths	Office Fathoms	Office Tenths
	08 49 –	45	0	+0.2	-0.8	+0.2	44	6		
	30	55	0*	+0.5			55	0		
	50	58	5				58	5		
7	08 50 30	63	–				63	–		
8	08 52 00	67	–				67	–		
	30	M	–				–			
	53	59	5				59	5		
	30	53	–	+0.6			53	0		
9	54 –	49	–*	+0.2			48	6		
	30	42	5				42	1		
	55	38	5		-0.8		38	1		
	½	35	0		-0.6		34	8		
	30	41	5				41	3		
10	08 56 00	29	4				29	2		
	30	25	6				25	4		
	57 –	30	6	+0.2			30	4		
	⅔	15	6	0.0			15	2		
	30	21	0				20	6		
11	58 –	11	6*				11	2		
	30	7	3				6	9		
	½*									
	59 –	5	2	0.0	-0.6	+0.2	4	8		

Bottom / Heading by / Compass	Position Number	Position Control Data		Remarks
		Hook	Fang	Running Arcs
				* B scale
	7	11.265	12.106	LTLA
		-.017	-.004	
		11.248	12.102	
	8	11.295	12.210	LR
		-.017	-.004	
		11.278	12.206	
		No. 102 ZERO CHECK		
		Station Name	Hook	Fang
		ZERO SET	99 820	99 820
		Zero Check	99.830	99 823
		Correction	-.010	-.003
	9	11.057	12.205	* A scale
		-.017	-.004	
		11.040	12.201	
	10	10.795	12.206	
		-.017	-.004	
		10.778	12.202	SW breeze increaseing to force 3.
	11	10.525	12.210	* Sl. S.
		-.017	-.004	
		10.508	12.206	
				*Rk. bare 3 ft. Approx. 20m. stbd.

FIGURE 65.—Record of echo soundings with Shoran control and entries properly made. (Double page of sounding record reduced about one-half.)

There is no objection to changing from one unit to another in the sounding record, but where such change is made, it must be clearly indicated. Since only one unit is used on one hydrographic sheet, it is more convenient to record soundings in the unit to be used in plotting where practicable, and that changes from one unit to another be held to a minimum consistent with the accuracy required (see 5–63).

When soundings are obtained simultaneously by two instruments, the source of each must be shown. For example, if most soundings are scaled from a fathogram and hand

Locality
COAST OF MAINE

Date JULY 23 1958

16-68165-2

POSITION NUMBER	TIME MER 75 (h m s)	SOUNDINGS FEET	SOUNDINGS TENTHS	CORRECTIONS ECHO FEET	CORRECTIONS TIDE REDUCER FEET	CORRECTIONS FEET	REDUCED SOUNDINGS FIELD FEET	REDUCED SOUNDINGS FIELD TENTHS	REDUCED SOUNDINGS OFFICE FEET	REDUCED SOUNDINGS OFFICE TENTHS
157	15 26 00	78		-0.5	-2.5	0.0	75			
	20	70					67			
	40	62	5*	-0.4	-2.4	-0.2	59	5		
	27-	53	0				50	-		
	20	42	5				39	5		
	½	37	0				34	-		
158	40	40	5				37	5		
	28-	32	0	-0.4			29	-		
	20	21	0	-0.2			18	2		
	⅓	8	4	0.0			5	8		
	40	13	5	-0.2	-2.4		10	7		
	29-	11	5		-2.2	-0.2	8	9		
159	20	10	5	-0.2		0.0	8	1		
	40	6	0	0.0			3	8		
	30-	4	5*				2	3		
		7	5	0.0			5	3		
160	20	10	-	-0.2	-2.2		7	6		
161	16 57-	12	2	-0.2	-0.8	0.0	11	2		
		12	0HL				11	2		

Sublocality
FRENCHMAN BAY

Boat used LAUNCH 182 ; d day

BOTTOM / HEADING BY Boat COMPASS	POSITION NUMBER	POSITION CONTROL DATA		REMARKS
010	157	Leg	51 40	Phasemeter 60.1
		Nay	4	adjusted to 60.0
		Ole	24 03	
		Kim-Nay	32-16	Cut to check
				⊙ Kim
				* A scale
005				
	158	S	74 51	
			30 51	
				Nun No.2 30m. port.
				Adjusted initial
	159	Got	52 45	51.S. Entering
		Leg		Kelp
		Ole	101 44	
				*RK. bare 2ft. 10
				m ~~oo~~ Kim.
				Leaving Kelp
	160	Leg	77 11	Line breaks to
		Ole		Search shoal.
		Par	84 58	
RK.	161	Leg	34 09	Least depth on
		Nay		sharp pinnacle RK.
		Ole	63 55	Item No.4 of

presurvey review. Searched area with leadlines for 1hr. & 20 min. Bottom not visible. Scattered Kelp in surrounding area.

FIGURE 66.—Record of echo soundings with sextant angle control. (Double page of sounding record reduced about one-half.)

lead soundings are interspersed, each hand lead sounding shall be identified by the letters "HL." Similarly, pole soundings shall be identified by the letter "P," and wire soundings by the letters "VC" (vertical cast). Soundings by leadline, pole, or wire must not be recorded unless they are true vertical measurements of the depth. Slope measurements occur most frequently when a wire sounding machine is being used to obtain bottom samples.

The character of the bottom shall be entered in the first column on the right-hand page using the abbreviations listed in 5–88.

Detached determinations of the character of the bottom must always be accompanied by position data.

The vessel's heading by compass must always be entered except when lines are being run along distance arcs in launch hydrography. Indicate in the space at the top of the column whether a steering, standard, gyro, or boat compass is being used. A course change shall be entered on the line corresponding to the time it is made. All courses shall be entered in degrees clockwise from north.

5–96 **Position data.**—Insofar as practicable, all position data shall be entered in the column headed "Position Control Data" on the right-hand page. The first entry of position data shall invariably be on the same horizontal line with the corresponding time on the left-hand page, followed on consecutive lines by the remainder of the position data.

The names of the three stations of a three-point fix shall be recorded vertically in the left part of the column. The recorded names of signals must agree with those on the boat sheet. The objects shall always be recorded clockwise, that is, the left object first, the center object next, and the right object last (see Fig. 64). The angles are recorded in the right part of the column, the left and right angles being recorded opposite the names of the left and right objects respectively. Where the same control stations are used for successive fixes, it is not necessary to repeat the names; the word "same" or the letter S, covering the three spaces occupied by the fix, may be used to indicate a repetition, except that the names must be recorded at the top of each page. All station names must be entered if any station in the fix is changed.

Supplemental angles, cuts, or check angles are entered in the same column below the fix and the names of the objects are entered on the same line. The name of the left object is recorded first. Detached positions are frequently recorded without a sounding as when locating rocks or signals. All such positions shall be assigned a number and recorded in the same manner as for hydrography.

Electronic control systems furnish positioning data on two dials, one for each ground station. The dials shall always be read and recorded from left to right, and the readings correctly related to the shore stations. When Shoran is used, the left dial is for the "rate" station, and the right is for the "drift" station. A flip of a switch on the indicator can reverse the two stations and a change of this kind must be recorded. EPI cannot be changed at the ship, but changes can be made at the shore stations to reverse the stations on the controller-indicator. In Raydist, the "red" station distance readings always appear on the left-hand phasemeter dial.

Rubber stamps are available for use in the sounding record to record position data furnished by the various electronic control systems. It is usually more convenient to record the data in a double column, each one headed by the station name. Both distances are recorded on the same line (Fig. 65) and as they are read from left to right on the instrument.

Calibration and other corrections must be applied to electronic position data, and several spaces between positions should be left for this purpose. If sextant fixes, cuts, or bearings are observed at the position, the data should be recorded in the remarks column and referenced to the position.

5–97 **Remarks column.**—All additional information required for the proper understanding and correct plotting of the work, for which provision is not made in other columns, shall be entered in the remarks column. Abbreviations (see 5–87) may be used for many entries. Where notes are too long to be entered in the remarks column, the sequence of recording may be interrupted to record a note the entire width of a page. As a rule, all notes should be entered at the time the event described occurs. The hydrographer should initial expanatory notes which he enters in the record.

A great number of miscellaneous entries are required, too numerous to be discussed

individually, but the following list illustrates the variety of information which should be recorded:

(a) The latitude and longitude of the first position at the beginning of the first line of the day's work, of each detached position, and of the beginning of a line in a locality different from the last position shall be noted. Rubber Stamp No. 39 may be used (Fig. 67). A scaled distance and direction from a nearby signal may be used in lieu of the latitude and longitude of the position.

(b) The abbreviations LTLA or LTRA shall be entered when the line turns left or right about to an adjacent line and LR, line resumes, at the first position of the new line.

(c) Note any changes affecting the information given at the beginning of the day's work, as personnel, instruments, weather, etc.

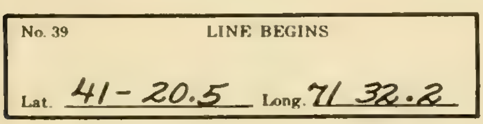
(d) Distance (in meters) and direction of features in the water area, such as aids to navigation, rocks, breakers, kelp, etc., shall be noted and referenced to the time of passing. Indicate whether the distance is estimated, whether the object has been previously located, or whether the data recorded are to be used to locate it.

(e) Note estimated distances to the high-water line, low-water line, reef lines, etc., from the nearest recorded position.

(f) Note all changes in speed of the sounding vessel. Note any sounding line started from a standstill and the time of reaching sounding speed (see 5–58).

(g) Indicate the scale or phase being used in echo sounding and all scale changes as they occur. When shoal and deep water echo sounders are used alternately, each change shall be recorded.

(h) Enter notes concerning the correct operation of the echo sounder. Frequent checks on the 808 tachometer are required


No. 39 LINE BEGINS

Lat. 41 - 20.5 Long. 71 32.2

FIGURE 67.—Facsimile of hydrographic stamp No. 39.

and shall be noted in the record. The note "MRV," meaning "middle reed vibrating" should be used to indicate the correct operation of this instrument. Adjustments of of stylus length should be noted. The frequency meter reading on an EDO–255 echo sounder should be recorded at frequent intervals.

(i) All pertinent information received from shore stations shall be recorded with proper reference to time, such as time comparisons, changes in equipment, orientation of Shoran reflectors, etc.

(j) Shoran and EPI zero check observations should be entered in this column.

(k) Enter measurements or estimates of heights of exposed rocks, and estimated depths over submerged features which cannot be sounded over.

(l) Complete and comprehensive notes regarding the examination of shoals shall be recorded, including the method of search used, a statement as to whether or not the bottom was visible, kind of bottom, presence or absence of kelp or grass, least depths found, and any additional information which will assist the reviewer to determine whether or not the examination is adequate.

(m) Each marked feature in the presurvey review must be examined and the results noted as in (l). The item should be identified by number or latitude and longitude. The note shall include a statement as to the amount of time spent in making the investigation. A recommendation to delete the feature from the chart must be supported by the reasons therefore (see 1–5).

5–98 **Information at end of day's work.**—At the end of the day's work certain entries are required to complete the record. Most of this information can be entered in the spaces provided in rubber stamps. A bar check or leadline comparison is required and the data entered under rubber Stamp No. 35 (see 5–93).

The time of arrival at the anchorage or headquarters and the distance run shall be entered in Stamp No. 34.

A verification of the correct adjustment

No. 36	
Sextants *OK*	Clock *2' slow*
Sounding records inspected:	
J. A. Sharp	Officer-in-charge
M. W. T.	Chief of Party

FIGURE 68.—Facsimile of hydrographic stamp No. 36.

of the sextants and clock used is required at the end of the day using Stamp No. 36 (Fig. 68). This stamp also includes spaces for the signature of the officer-in-charge and the chief of party.

The statistics for each day's work shall be given at the end of each day's work, using rubber Stamp No. 37 (Fig. 69). Where a day's work is recorded in two volumes, the statistics shall be divided between the two volumes, the stamp being used at the end of the first volume as well as at the end of the day in the second volume. The stamp provides for this division and a total for the day. Echo soundings are not to be counted—note that the stamp specifically indicates that only handlead and wire soundings are to be counted.

All distances shall be entered in nautical miles; conversion to statute miles on line three of the stamp may be omitted.

Rubber Stamp No. 38, Processing (Fig. 70) is required in connection with the reduction of the records. Unless this stamp is impressed as each day's work is completed, space must be left for it. The location of the tide gage used during the day shall be entered in this stamp in the space provided.

5–99 Completion of sounding records.—Reduction of soundings procedures are discussed in subsequent sections of this chapter;

No. 37	STATISTICS *F* DAY		
		This vol.	Total:
No. sdgs. (H.L. and wire)		*4*	*10*
No. Positions		*54*	*176*
Miles sdg. line *47.6* Naut.			Stat.
Dist. to and from *3.7* Naut. Mi.			
Misc. dist. run *1.4* Naut. Mi.			*52.7* Naut.
Sounding continued in volume			

FIGURE 69.—Stamp used to record hydrographic statistics in sounding record.

No. 38	PROCESSING	
Portable Tide Gage at *Temple Cove*		
Plane of Ref *M.L.L.W.*	Entered	Checked
Tide Red	*GCA*	*ANS*
Leadline Cor.		
Index Cor.	*GCA*	*ANS*
Vel Cor	*MRC*	*ANS*
Soundings reduced	*JRS*	*NLP*
Positions plotted	*NLP*	
Graph scaled	*JRS*	
Soundings penciled	*NLP*	

FIGURE 70.—Processing stamp with entries properly made.

and smooth sheet plotting procedures are described in Chapter 6. Work on the records required by this section may be done at any time after the survey is completed, but must be accomplished before the smooth sheet and records are forwarded to the Washington Office. If the smooth sheet is to be plotted at a processing office, the records shall be completed before they are transmitted to that office.

After the survey is completed, all the sounding records for that survey shall be gathered together and the following steps accomplished:

(a) The records shall be grouped in the proper order, the various groups combined, and the complete set numbered consecutively and permanently, including any volumes used solely for cuts or other miscellaneous data (see 1–32).

(b) The data called for on the cover label shall be entered in black drawing ink, except the position numbers and day letters, which shall be entered with ink of the color used in the record. Two entries are required for the hydrographic sheet number: the field number and the registry number. Rubber stamps, when available, may be used for some of the entries.

(c) On ships which use a magnetic steering compass, the deviation table for the compass shall be entered on page 1 of the first volume of each set of records, and in the proper record with reference to date if changed during the survey. Deviation tables are not required for launches or other small boats using portable compasses (see 2–28).

(d) An index of all objects such as signals, landmarks, rocks, aids to navigation, and breakers, the positions of which have been determined by sextant angles shall be entered as follows: The recorder shall make an appropriate entry on page 2 of the volume in which the data are recorded, and the entry shall be repeated in volume one of the set of records. If the data concerns a presurvey review item, reference to the item number should be made.

(e) All calibrations shall be indexed on page 2 of the volume in which the data are recorded, including bar checks, vertical cast comparisons, phase comparisons, leadline comparisons, and calibrations of Shoran, EPI, or Raydist equipment.

Correction of Soundings

5–100 General requirement.—Recorded sounds must be corrected for any departure from true depth due to the method of sounding or to a fault in the measuring apparatus and for the height of the tide above or below the plane of reference at the time of sounding (see 1–39). Vertical columns are provided in the sounding record for entering the various corrections and the corrected soundings.

Corrections (often called reducers) shall be entered in the same unit in which the soundings have been recorded, either fathoms or feet, and parts of units shall be entered as decimals.

Each correction, with its arithmetical sign, shall be entered on the horizontal line opposite the first sounding to which it applies and need not be repeated, except opposite the first sounding on each page. A correction once entered shall be considered applicable to all following soundings until a different correction or sign is entered.

Specific rules for determination and application of various types of corrections are stated in the following sections.

5–101 Correction units.—Corrections to soundings shall be entered according to Table 2. It should be noted that, in general, the corrections are to be entered to a decimal which is one-half that required in recording the soundings, using 0.2 where the requirement for recording is 0.5. Exceptions are: that no entry in fathoms need be closer than 0.1 fathom; and for soundings in feet, except on shoals, banks, and other critical areas, corrections need be entered only to the nearest foot. Used in conjunction with Table 2, the following tabulations may be helpful:

Where soundings are re-recorded to the nearest—	Enter corrections to the nearest—
Foot	*Foot*
0.2	0.2
0.5	0.2
1.0	0.5 } see text above.
1.0	1.0 } see text above.
Fathom	*Fathom*
0.1	0.1
0.2	0.1
0.5	0.2
1.0	0.5
2.0	1.0
5.0	2.0
10.0	4.0

The range through which any correction is to be applied is as follows:

Where corrections are entered to the nearest 0.5 foot or less, and to the nearest 0.1 fathom, the range covered shall be from one-half below to one-half above the correction applied, according to the following tabulation:

Whether *added* to or *subtracted* from the sounding

Range

0.1 to 0.3 foot = 0.2 foot.
0.3 to 0.5 foot = 0.4 foot.
0.5 to 0.7 foot = 0.6 foot.
etc.

0.25 to 0.75 foot = 0.5 foot.
0.75 to 1.25 feet = 1.0 foot
1.25 to 1.75 feet = 1.5 feet
etc.

0.05 to 0.15 fathom = 0.1 fathom.
0.15 to 0.25 fathom = 0.2 fathom.
0.25 to 0.35 fathom = 0.3 fathom.
etc.

Where corrections are entered to the nearest 1.0 foot or to the nearest 0.2 fathom or greater, the range covered shall be eccentric, from one-fourth below to three-fourths above the correction applied, or vice versa, according to the following tabulations:

Range

Corrections added

-0.25 to 0.75 foot = 0 foot.
0.75 to 1.75 feet = 1.0 foot.
1.75 to 2.75 feet = 2.0 feet.
etc.
-0.05 to 0.15 fathom = 0 fathom.
0.15 to 0.35 fathom = 0.2 fathom.
0.35 to 0.55 fathom = 0.4 fathom.
etc.
-0.125 to 0.375 fathom = 0. fathom.
0.375 to 0.875 fathom = 0.5 fathom.
0.875 to 1.375 fathom = 1.0 fathom.
etc.
-0.25 to 0.75 fathom = 0 fathoms.
0.75 to 1.75 fathoms = 1.0 fathoms.
1.75 to 2.75 fathoms = 2.0 fathoms.
etc.
-0.5 to 1.5 fathoms = 0 fathoms.
1.5 to 3.5 fathoms = 2.0 fathoms.
3.0 to 5.5 fathoms = 4.0 fathoms.
etc.
-1.0 to 3.0 fathoms = 0 fathoms.
3.0 to 7.0 fathoms = 4.0 fathoms.
7.0 to 11.0 fathoms = 8.0 fathoms.

Corrections subtracted

-0.25 to -1.25 feet = -1.0 foot.
-1.25 to -2.25 feet = -2.0 feet.
etc.
-0.05 to -0.25 fathom = -0.2 fathom.
-0.25 to -0.45 fathom = -0.4 fathom.
etc.
-0.125 to -0.625 fathom = -0.5 fathom.
-0.625 to -1.125 fathoms = -2.0 fathoms.
etc.
-0.25 to -1.25 fathoms = -1.0 fathoms.
-1.25 to -2.25 fathoms = -1.0 fathom.
etc.
-0.5 to -2.5 fathoms = -2.0 fathoms.
-2.5 to -4.5 fathoms = -4.0 fathoms.
etc.
-1.0 to -5.0 fathoms = -4.0 fathoms.
-5.0 to -9.0 fathoms = -8.0 fathoms.
etc.

In depths over 101 fathoms, recorded soundings shall be corrected in intervals of 1.0, 2.0, 5.0 and 10.0 fathoms when the corrections are entered in units of 0.5, 1.0, 2.0 and 4.0 fathoms, respectively. If the algebraic sum of the individual corrections does not add up to a multiple of one of the intervals given above, it shall be arbitrarily changed to the nearest multiple. When halfway between two intervals, it shall be changed so as to increase negative corrections and decrease additive corrections. Thus when soundings are recorded to 1.0-fathom intervals, and the algebraic sum of the corrections is —3.5 fathoms, a —4.0 fathoms correction shall be made to each sounding. When soundings are recorded to the nearest 5-fathom interval and the algebraic sum of the corrections is —2.5 fathoms, a correction of —5 fathoms shall be applied, but a correction of +2.5 fathoms shall be arbitrarily reduced to 0.

When no corrections are to be applied to the recorded soundings, the word "Same" shall be written at the head of, or in, the FIELD column under the heading REDUCED SOUNDINGS, and the soundings shall not be transferred to the latter column.

In all areas in depths over 101 fathoms, corrections shall be omitted where the algebraic sum of the tide correction and other corrections, excluding velocity corrections (see 5–114) is less than half of one percent of the depth. In offshore coastal areas, tide corrections shall be omitted in depths greater than 101 fathoms and shall not be used in computation of the total algebraic sum of corrections.

5–102 Tide reducers.—Except as stated in 5–101, all soundings must be corrected for the height of the tide above or below the tidal datum plane adopted for the area. For the Atlantic Ocean and Gulf of Mexico the plane of reference is the mean of the low waters (MLW) ; and for the Pacific Ocean the plane of reference is the mean of the lower low waters (MLLW) (see 1–45).

The tide reducers are derived from automatic tide gages at standard stations, or from automatic tide gages established in the project area for this purpose. Occasionally the reducers may come from observed tides (heights read from a staff) (see 2–49 and 50).

Predicted tides are generally used to reduce soundings for plotting on the boat sheet (see 5–63) but the final reducers to be entered in the sounding record reflect the actual rise and fall of the tide as nearly as possible. For new tide stations the marigrams must be sent to the Washington Office where the plane of reference is determined. In such cases the hourly heights must be scaled for the periods when soundings were recorded so that the tide curve can be reconstructed at a later date.

Three printed forms are available for reconstruction of tide curves as follows:

Form 114 for reducers entered to 0.2 foot.
Form 115 for reducers entered to 0.5 foot.

Form 116 for reducers entered in fathoms.

In some areas it is necessary to use tide zones between adjacent tide stations because of time or range differences. Procedures for making time and height allowances are explained in Special Publication No. 196, Sections 255–258. Tide zones are established by the Washington Office on request. Zoning is often critical in estuaries and in long narrow bays having a large range of tide. Improper zoning in such areas is reflected in the junctions with adjacent surveys and may cause excessive differences in depths at crossings within the survey (see 1–26e).

5–103 Leadline corrections.—The leadline shall be compared with a standard length each day it is used and the results recorded in the sounding record under the headings in rubber Stamp No. 35. All leadline soundings for that day shall be corrected, if necessary, in accordance with the comparison (see 3–67). The corrections are entered in the column headed "Leadline."

5–104 Wire sounding corrections.—The registering sheave used in wire sounding shall be calibrated in accordance with 3–73 and all wire soundings shall be corrected if necessary. To correct wire soundings, multiply the observed depth by the sheave factor, apply the tide correction, and enter the result in the column headed "Field."

5–105 Echo-sounding corrections.—Echo-sounding instruments are intended to be adjusted and operated so that the velocity and tide corrections are the only corrections that need to be applied to echo soundings. It is sometimes necessary to apply other corrections such as variation of the initial from the adopted setting, incorrect speed of operation, and similar instrumental errors or faults of operation. Each source of error is discussed in the following sections.

When sounding operations are in progress, the hydrographer may become so engrossed with measurements in a horizontal plane that the problems involved with measurements of the depth are neglected. The fact that an echo sounder appears to be operating correctly is not always sufficient evidence that the recorded soundings are correct. The detection of errors in positioning and sounding, and the accumulation of data for the correction of these errors presents a real challenge in many instances. The final measure of the quality of the work is found here.

Occasionally inconsistencies are not discovered until the survey is smooth plotted. The available data should be adequate to permit a reasonable solution of the problems and a proper adjustment of discrepancies. The following examples indicate the variety of problems encountered in smooth plotting and verifying a survey.

A launch was equipped with two echo sounders, one of which was used to obtain soundings on the regular system of lines. The second instrument was used at a later date to run cross lines and closely spaced lines for development of shoal indications. The bar checks taken with each instrument were satisfactory, but recorded soundings were consistently different by 2 feet. There were no vertical cast comparisons with either instrument. There is no evidence to prove which soundings are correct.

At the junction of hydrography accomplished by a launch with that done by another vessel, the differences in depths range from 2 to 5 feet with a fairly consistent difference of 3 feet. The launch made bar check observations at a remote area but not in the area covered by the hydrography. Neither vessel recorded a vertical cast comparison. Obviously, the soundings recorded by at least one unit are in error, perhaps both are incorrect.

As a general rule, the accuracy of soundings obtained by portable echo sounders is directly related to the competence and reliability of the technicians who operate the instruments. Each type of echo sounder has characteristic features which must be closely watched, such as voltage, gain, paper speed, phase, paper alignment, initial setting, frequency, and stylus length. Failure to maintain proper adjustments results in erratic

depth recordings which must be rejected or laboriously corrected. See Chapter 3.

5–106 Draft correction.—Draft, instrumental error, and settlement and squat are factors for which compensation may be made by an appropriate adjustment of the instrument. The effect of each of these is determined individually and then combined algebraically into a total for which allowance is made by setting the index of the instrument.

The depth of water registered by an echo sounder should be the depth below the surface of the water, and not the depth below the submerged acoustic units. Draft with reference to echo-sounding corrections shall be understood to mean the depth of the transducer below the surface of the water when the ship is not underway.

Provision must be made, or special instruments must be installed, to measure the draft of the acoustic units permanently mounted in the hull. An internal draft gage may be installed by which the draft of the units may be read directly. The method most commonly used is to mark points on the rail or deck above and abeam of the units. Knowing the vertical distance of these marks above the units, their draft can be determined at any time by measuring the vertical distance of the reference marks above the water surface and taking the difference between the vertical distances. The reference marks should be established on both port and starboard rails and measurements to the water surface made from both points. The elevation of the reference marks above the acoustic units is determined while the ship is in drydock with the aid of an engineer's level and a steel tape.

The variation of the ship's draft and the depth of the water are the two factors which determine the frequency of draft measurements. For soundings of 10 fathoms or less, the draft should be known within one-fourth foot and should be measured with sufficient frequency to insure this. For soundings deeper than 10 fathoms, the draft should be known within at least one-half percent of the depth of the water. For sounding in deep water where the possible error due to erroneous draft adjustment is a small percentage of the total depth, echo sounders are usually adjusted for a mean draft.

5–107 Instrumental error.—Errors caused by instrumental time lags are inherent in all echo-sounding instruments, and some have mechanical lags. Their effect on echo sounding is to increase the registered depth. Such errors differ for each type of instrument and are unlikely to be exactly the same for instruments of the same design. Furthermore, such errors are variable in which changes may be attributed to: (1) variation of tuning and gain of the echo amplifier; (2) variation in strength of the transmitted and echo signals; (3) adjustment of the keying circuit; and (4) deterioration of tubes and parts. There are other minor causes of slight errors. Sounding at incorrect frequencies or speeds are considered operational errors rather than instrumental errors.

Perhaps the most troublesome source of instrumental time lag is that due to a variation in the strength of the echo signal. As its strength decreases, the recorded depth increases and is always too large. This may be the result of varying the gain of the amplifier or a variation in the strength of the echo. The amplifier must always be operated at the highest gain practicable without introducing too many strays, and must not be less than the gain setting used when making bar checks. The strength of the echo signal is partly a function of the depth, but is also affected by the character of the bottom and the characteristics of the water.

The instrumental errors are usually small and are principally additive, but their total may be of such magnitude as to require correction or instrumental compensation. The amount of the error should be determined periodically and compensated for instrumentally. It is especially important that this be done where the survey includes precise sounding in shoal water.

There are two methods for determining the amount of the instrumental error: (1) by comparing echo sounding with simul-

taneous direct vertical measurements of the depth; and (2) by bar check. When good results can be obtained by bar check, it is the more accurate method and should be used. Regardless of the method used, the procedure is generally as follows:

(a) The daily check of adjustments should be made and the instrument should be operated for about 30 minutes before the test is made.

(b) The vessel must be stopped, the sea calm, and the current slack. If vertical casts are to be made, the bottom should be level and comparatively hard.

(c) The echo sounder initial should be set to compensate for the draft of the transducer, uncorrected for settlement and squat.

(d) When simultaneous comparisons are used, at least 5 comparisons shall be recorded. If a bar check is used, comparisons should be made at a depth of about two fathoms.

(e) Sheave or leadline corrections shall be applied to vertical measurements and temperature and salinity corrections to the echo soundings. The difference between the corrected depths is the instrumental error.

The instrument error of an echo sounder shall be determined at the beginning of a season, whenever the instrument is repaired or changed by replacement of tubes or parts, and whenever instability of operation is suspected. The error should be redetermined at intervals of about one month during the season.

The ship and each launch to be used in sounding operations should make this test and each depth recorder to be used during the season should be tested. The information thus obtained should disclose instrumental errors such as those mentioned in 5–105. It must not be assumed that the characteristics of the echo sounders determined by this test will remain constant over a long period of time. Similar tests or vertical cast comparisons shall be made whenever a change in the instrumental error is suspected.

5–108 Settlement and squat.—Although an echo-sounding instrument correctly registers the depth from a vessel when stopped, there is no assurance that the correct depth will be registered when the vessel is underway. This is because a point on the vessel may experience a vertical displacement when the vessel is underway, relative to its position at rest. Acoustic units in a ship's hull are affected by such a vertical displacement, depending on their location. The magnitude of this displacement may be such as to warrant compensation, especially where precise soundings in shoal water are to be obtained from a vessel running at moderate to high speeds. The factors accountable for this vertical displacement are settlement and squat.

Settlement is the general lowering in level of a moving vessel, relative to what its level would be were it motionless. Settlement is due to a regional depression of the surface of the water in which the ship moves. It is not an increase in displacement and, therefore, cannot be determined by reference to the water in the immediate vicinity of the ship.

Squat refers to the change in trim of the vessel when underway. At speeds ordinarily used in surveying, squat manifests itself in a lowering of the vessel's stern and a rise of the bow.

The major factors which influence settlement and squat are hull shape, speed, and depth of water under the vessel. The effect of squat on the draft of the acoustic units is usually not appreciable if they are mounted amidships, or a little forward of amidships, as they generally are. On the contrary, settlement may be quite appreciable at normal sounding speeds. In depths approximately seven times the draft, for a survey ship it will probably amount to about one-half foot and in extreme cases may be as much as 1 foot, increasing slightly as the depth lessens.

The combined effect of settlement and squat at various sounding speeds used, shall be determined for each survey vessel, including auxiliaries and launches, used for hydrographic surveying in shoal or moderate depths. A test to determine this for each vessel should be made at the beginning of each season. The vessel should be carrying

an average load and be in average trim. This value may be assumed to be a constant for the season's work. Where the result of the test shows that the combined effect of settlement and squat is less than 0.2 foot, it may be neglected, but if it is more than this, an instrumental adjustment should be made to all echo-sounding instruments used in shoal water to compensate for it, or an arithmetical correction must be made to the soundings.

Where the index has been adjusted to compensate for the amount of settlement and squat at normal sounding speed, it is necessary to make an arithmetical correction to any soundings taken from the vessel while stationary or running at slow speed.

Either of two methods may be employed to determine the combined effect of settlement and squat, but the first method described is preferred. In both, the tests should be made at either high or low water, when the tide level is varying slowly. Provision must be made to measure any tidal change which does occur during the tests.

The tests should be made at a place where the bottom is known to be smooth and level and in a depth of water which is approximately seven times the draft of the survey vessel. If the survey vessel is habitually used to survey in depths considerably less than this, an additional test should be made at the lesser depth.

First method: A leveling instrument may be mounted on shore, preferably on the end of a pier off which are the required conditions as to depth and bottom, and past which the vessel can run at normal sounding speed. A marker buoy should be anchored with a short scope at the point where the test is to be made.

With the vessel stopped at the marker buoy, a level rod is held on board the vessel vertically over the transmitting and receiving units, or over the mid-point between them if one is forward of the other, and the level rod is read with the instrument on shore. The height of the tide should be noted. Then the vessel should run past the marker buoy at normal sounding speed, with the rod held on the same spot, and the rod should be read again with the same instrument on shore. The difference between the two readings, corrected for tidal changes, will be a measure of the combined effect of settlement and squat at the location of the acoustic units. Several such tests should be made and a mean of the results used.

Second method: Select an area which satisfies the requirements as to depth and bottom and anchor a marker buoy with a short scope. With the vessel stopped alongside the marker buoy the depth of water should be measured accurately with an echo-sounding instrument. Then the vessel should run past the marker buoy at normal sounding speed, taking another accurate echo sounding when in the same position relative to the buoy. Provision must be made for a record of the tidal change during the test. The difference between the echo soundings underway and stopped, corrected for change in tide, will be the combined amount of settlement and squat. The test should be repeated several times and the average value determined.

5–109 Adjustment of index.—All echo-sounding instruments used by the Coast and Geodetic Survey are provided with facilities for adjusting the index, or initial setting. On portable sounders the adjustment is accomplished by means of a knob on the cover of the instrument. Adjustment of the index on the EDO–185 is less easily accomplished and shall be made only by a qualified technician.

The index may be set to compensate for the algebraic sum of the draft of the transducer, settlement and squat, and instrumental error, but it is more easily maintained on one of the printed lines on the fathogram. The index should be maintained at the adopted position and arithmetical corrections to soundings are required for variations from the correct setting.

When the speed of operation of an echo sounder is changed the value of the initial setting is changed. For example, an 808 recorder can be operated to sound in units of feet or fathoms. If the initial is set at 2 feet and the mode is changed from feet to fathoms, the value of the initial setting is

changed to 2 fathoms thus introducing an error of 10 feet. A change in mode of operation does not affect the position of the initial mark on the graph.

5–110 Bar checks.—Reliable bar checks (see 3–109) can be made only under the most favorable conditions. When the sea is calm and there is little current to displace the bar from a position vertically below the transducer, bar checks can be obtained in depths as great as 15 fathoms, but under less favorable conditions the maximum bar-check depth may be as little as 2 fathoms. In moderate depths where bar checks and vertical cast comparisons can be obtained over the full depth range, it is possible to determine the corrections to be applied for the difference between the calibrated velocity of the instrument and the actual velocity of sound in the water.

All launches and small boats using echo sounders in hydrographic surveying shall make and record bar checks under the following conditions and at the following frequencies:

(a) In protected waters where there is every reason to believe the results of the bar checks are dependable, and the range of depths sounded can be covered by the bar-check range, bar checks shall be made on the descent and ascent of the bar at each 10 feet throughout the range of depths sounded three times daily—at the beginning and end of the day's work and once near the middle of the day.

(b) Where most of the depths sounded are beyond the range of the bar check, other conditions being as in (a), one check shall be made at the deepest depth at which a dependable result can be obtained, and one check shall be made at a depth in the overlap between phases—three times a day as in (a).

(c) In exposed waters, where dependable results cannot be obtained, a bar check shall be made at 10 feet or 2 fathoms (preferably in a protected place) at least twice, and preferably three times daily—but no other bar checks shall be made.

(d) The index or initial shall be set to coincide with a line on the fathogram which closely approximates the draft of the transducers when sounding in feet. The initial should be set and maintained on the zero line on all launches when sounding in fathoms, or when it is necessary to sound part of the area in feet and part in fathoms.

(e) Where the results of bar checks are to be used for correcting or compensating for the velocity of sound, not less than three complete bar checks per day shall be made, the bar check must cover at least 75 percent of the range of depths sounded, and the bar checks must be most accurate and dependable (see 5–115).

When an 808 fathometer is used, a speed count should be observed and recorded. The stylus arm should make 123 revolutions in 66 seconds in the fathom mode when the calibration velocity is 820 fathoms per second and with the middle reed of the tachometer vibrating at maximum amplitude. For a calibrated velocity of 800 fathoms per second the arm should make 120 revolutions in 66 seconds. A well-regulated stop watch shall be used when making this check (see 3–91). When the speed count fails to agree with these standards, the paper speed test described in 5–111 should be made.

If an EDO–255 echo sounder is used the frequency meter reading shall be recorded.

The gain setting shall be recorded for each depth of the bar.

When making a bar check in depths of 20 fathoms or less, a leadline sounding shall be taken and compared with the echo sounding observed simultaneously.

All bar check data shall be recorded under Stamp No. 35.

5–111 Sources of errors in 808 echo soundings.—The circular sweep system of recording and the mechanical method of phase shifting employed by 808 type echo sounders introduce sources of error which are not found in other designs. The 808 fathometer is described and its operating characteristics are stated in Chapter 3. Unless the instrument is adjusted and operated in accordance with those specifications, the

soundings will be inaccurate and corrections must be made in the sounding record.

The principal sources of error are: (1) incorrect paper speed and speed of rotation; (2) incorrect radius of rotation of the stylus arm; (3) incorrect alignment of the paper; and (4) improper phase shifting.

There are two methods of checking the operating speed of the instrument and the correct balance of the tachometer. The first is the speed count described in the previous section. The second check is made by running the instrument in the feet mode and measuring the rate of paper movement. With the instrument properly warmed up, make a fix mark on the paper and start an accurate stop watch simultaneously. Exactly 4 minutes later scribe another fix mark on the graph; remove the paper and measure the distance between fix marks along the centerline of the paper. For a calibrated velocity of 820 fathoms per second, the paper should have traveled exactly 8 inches; and for a calibrated velocity of 800 fathoms per second, the paper should have moved 7.8 inches. The middle reed of the tachometer should be vibrating at maximum amplitude during such tests. If the speed count of the stylus arm or the rate of advance of the paper fail to agree with the correct speed or rate after repeated tests, the tachometer should be returned to the office for recalibration.

Although variations in motor speed are indicated by the changes in the rate of paper travel, care should be taken that paper slippage is not misinterpreted as a change in motor speed. The spring-belt drive on the paper rewind roller should maintain proper tension so that the paper is not pulled through the sprocket roller. Torn sprocket holes or loose paper are indications of improper paper speed not attributable to the motor speed.

The fathogram scanner should check the paper speed against the clock time recorded in the sounding record. If the paper travel is incorrect, the soundings shall be corrected by the percentage variation from the normal travel speed. Before applying speed corrections, it should be determined that the abnormal rate of travel is not due to paper slippage. Proper notes on the fathogram, or in the sounding record, should be made so as to preclude improper consideration of these discrepancies.

Adjustment of the stylus arm length is described in 3–92. Tests should be made and adjustments completed before the instrument is used for hydrography. The operator should make frequent checks of this adjustment by causing a fix mark to follow a printed arc on the fathogram. If the arcs coincide, the adjustment is correct. If the two arcs coincide at both ends of the printed arc, but not at the center, the needle should be adjusted.

If the arcs coincide at only one end of the printed arc, the paper alignment should be adjusted. Any large variation in the paper alignment (see 3–93) is likely to cause errors in the recorded soundings which are difficult to correct.

5–112 808 **phase corrections.**—The fathograms used in 808 fathometers have four printed scales of 55 fathoms (or feet) in each scale. An overlap of 20 units is provided on successive scales. A phasing head is provided for changing scales as necessary to record the returning echo. Theoretically, a sounding in the overlap area of successive scales should be the same on either scale. In practice this seldom occurs and the differences, or phase corrections, must be determined by comparison. Because of mechanical imperfections in the phase shifting mechanism it is imperative that phase changes shall always be made by rotating the phasing head in a clockwise direction as the locking pin falls into place. When shifting to a deeper phase, rotate the head in a counter-clockwise direction with the locking pin held against the spring until the pin is to the left of the socket. Release the pin and turn the head in a clockwise direction until the pin falls into place and the head will turn no farther.

Phase comparisons shall be made at the beginning of the season and once each month during the season in the overlap zones of the phases (scales) in use (see 3–94). The

comparisons shall be made with the vessel stopped or drifting slowly in calm water over an even or gently sloping bottom. A minimum of 10 simultaneous comparisons shall be made between soundings obtained in the overlap zones of the various scales.

Phase errors are not always constant, and when the results of phase comparisons made during the season differ significantly they should not be averaged. Abnormal phase corrections should be noted by the echo sounder operator and reported to the recorder during sounding operations.

5–113 Corrections to EDO–255 soundings.—The EDO–255 depth recorder (see 3–84) is designed to eliminate most of the operational and mechanical errors inherent in 808 depth recorders. However, it is not fool-proof and certain features must be monitored or corrections to soundings will be required.

With the initial or index correctly set and maintained there are two possible sources of error in EDO–255 depth recordings: incorrect frequency and improper phase adjustment. The instrument can be operated at a variable frequency and the converter or inverter must be adjusted whenever a variation from the adopted frequency is noted on the meter. A drift of 0.3 cycle will cause an error of one-half percent in the soundings. A change in frequency of 0.2 cycle or more shall be noted in the record book, the frequency shall be adjusted and the times noted. Corrections to soundings shall be applied as a percentage with respect to variation from the correct frequency.

Phase changes are accomplished electrically. The contacts for the various phases are adjusted on the bench (see 3–86) and will ordinarily maintain their positions so that there will be no phase correction. It should not be assumed that this is always true, and checks should be made on the bar when sounding in feet, and during hydrography in either mode. If it is found that a phase correction is required, the amount of the error shall be determined by the method described in 5–112, and the instrument adjusted to eliminate the error. All pertinent information shall be entered in the sounding record.

5–114 Velocity corrections.—In echo sounding the sound wave passes vertically downward and back through a column of water in which the velocity of sound differs at different depths, and since the true depth is a product of velocity and time, the average velocity from surface to bottom must be known at each sounding. The velocity of sound in sea water depends on the temperature, salinity, and pressure, and the velocity used in echo sounding is usually calculated from these characteristics (see 3–116).

The hydrostatic pressure increases in direct proportion to depth, the temperature decreases with depth but not uniformly, and salinity usually increases with depth. The result is that the velocity of sound is seldom uniform from top to bottom, and seasonal changes within any region will change the average velocity.

Echo sounders are calibrated for sounding at assumed velocities of 800 or 820 fathoms per second. The actual velocity of sound in sea water must be determined in all hydrographic surveys except in shoal areas where bar checks are used to determine corrections through the full depth range of soundings. Velocity corrections shall be ignored when they are less than one-half percent of the depth, but shall be applied when they equal or exceed one-half percent of the depth.

For use in correcting echo soundings the velocity of sound must be known with sufficient accuracy to ensure that no sounding will be in error from this cause alone by as much as one-half percent of the depth. Therefore, the mean velocity must be known within 7.5 meters per second. Of the characteristics of sea water affecting the velocity of sound, temperature is the most variable, and to satisfy the above requirements the mean temperature of the water must be known approximately within 2° C. A sufficient number of salinity and temperature observations must be made so that the velocity may be known with the specified accuracy. The number required depends on the physical characteristics of the water and the physiog-

raphy of the area. A minimum of one serial temperature shall be observed in the deepest part of the area surveyed each month.

There are several methods by which a correction for velocity may be determined. These are described in the following sections and any one of them may be used as may be appropriate for the depth.

5–115 Velocity correction by bar check.—For soundings in shoal water, the bar check can be used to derive corrections applicable to the various depths (see 3–109). Only bar checks taken under the most favorable conditions are considered sufficiently accurate for this purpose. The reliability of bar check results is influenced by the size of the reflecting surface of the bar, the frequency and beam width of the transducer, and condition of the sea. Bar checks of sufficient accuracy can seldom be obtained at depths greater than 60 feet. Where the maximum depth does not exceed 120 feet, the correction curve can be extended to this depth from simultaneous comparisons with accurate leadline or wire soundings.

Data obtained from bar checks and vertical cast comparisons shall be used to draw a correction curve. The hydrographer must use his judgment as to whether a number of bar checks should be averaged over a considerable period of time, and when a new correction curve should be drawn. Corrections which differ more than 0.4 foot shall not be averaged.

It should be emphasized that this method is not to be used unless exceptionally good results are obtained from bar checks and they are consistent enough to give reasonable assurance that the greatest part of the difference is due to the velocity of sound. Velocity corrections must not be extrapolated from a correction curve so obtained for depths greater than one-third more than the range of the bar checks (see 5–110).

5–116 Velocity correction by algebraic method.—In the algebraic method of computing velocity corrections, the column of water from surface to bottom is considered layer by layer and a correction for each depth layer determined. The summation of layer corrections will give the correction applicable to a given depth. The corrections may be derived numerically or graphically by procedures described in the following paragraphs.

All serial temperature and salinity observations are plotted on Form 121 and the curves drawn. Salinity in a project area will seldom change by an amount sufficient to affect the corrections appreciably. Therefore it is usually practicable to draw an average salinity curve for the entire season or project. This will not be true where large amounts of fresh water are discharged by rivers and under such circumstances a series of regional curves will be required. The temperature curves must be studied to determine how these can best be grouped by area or by time to permit mean curves to be drawn. The temperatures and salinities scaled from the mean regional or period curves for the midpoints of the adopted layers are used to derive the velocity corrections either numerically or graphically. It must be borne in mind that, to comply with requirements, the average temperature used to compute a correction must be within 2° C of the actual mean temperature.

5–117 Numerical determination of velocity corrections.—The standard form of velocity correction computations by the numerical method is illustrated in Table 11 with columns identified by the letters (A) to (H) for reference purposes only. It should not be assumed that all depth layers, for the purpose of determining velocity corrections, need to be chosen as shown in this example, but from past experience 5-fathom layers in the upper hundred fathoms, 20-fathom layers in the second hundred fathoms, and 200-fathom layers in greater depths have usually been found satisfactory. Where the change in temperature is regular with respect to depth and not too great, thicker layers may give sufficient accuracy.

The procedure, referring to Table 11, is as follows:

TABLE 11.—Example of velocity correction computations
(Computed for echo soundings taken with an instrument calibrated for a velocity of sound of 820 fathoms per second.)

(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
Mid-depth of each layer	Temperature	Salinity	Layer velocity	Correction factor	Layer correction	Depth correction	Applicable depth
Fathoms	°C.	0/00	*Meters per second*		*Fathoms*	*Fathoms*	*Fathoms*
4.5	19.6	33.6	1,516.1	+0.0110	+0.0550	+0.06	7
9.5	19.2	33.7	1,515.4	+0.0105	+0.0525	+0.11	12
14.5	18.5	33.8	1,513.7	+0.0094	+0.0470	+0.15	17
19.5	15.9	33.9	1,506.0	+0.0043	+0.0215	+0.18	22
24.5	10.7	34.0	1,488.8	−0.0072	−0.0360	+0.14	27
29.5	7.7	34.1	1,477.9	−0.0145	−0.0725	+0.07	32
34.5	8.4	34.3	1,481.0	−1.0124	−0.0620	+0.01	37
39.5	9.3	34.4	1,484.7	−0.0099	−0.0495	−0.04	42
44.5	10.4	34.6	1,488.9	−0.0071	−0.0355	−0.08	47
49.5	11.5	34.7	1,493.4	−0.0041	−0.0205	−0.10	52
54.5	12.1	34.9	1,495.9	−0.0025	−0.0125	−0.11	57
59.5	12.4	35.0	1,497.1	−0.0017	−0.0085	−0.12	62
64.5	12.5	35.2	1,497.8	−0.0012	−0.0060	−0.13	67
69.5	12.5	35.4	1,498.2	−0.0009	−0.0045	−0.13	72
74.5	12.4	35.6	1,498.3	−0.0009	−0.0045	−0.14	77
79.5	12.3	35.7	1,498.3	−0.0009	−0.0045	−0.14	82
84.5	12.1	35.8	1,498.0	−0.0011	−0.0055	−0.15	87
89.5	11.9	35.9	1,497.6	−0.0013	−0.0065	−0.15	92
94.5	11.7	36.0	1,497.1	−0.0017	−0.0085	−0.16	97
98.5	11.4	36.1	1,496.3	−0.0022	−0.0066	−0.17	100
110	11.1	36.1	1,495.6	−0.0027	−0.0540	−0.22	120
130	9.5	36.2	1,490.5	−0.0061	−0.1220	−0.34	140
150	8.5	36.2	1,487.4	−0.0081	−0.1620	−0.51	160
170	7.8	36.1	1,485.2	−0.0096	−0.1920	−0.70	180
190	6.7	36.0	1,481.8	−0.0119	−0.2380	−0.94	200
300	5.4	34.5	1,478.3	−0.0142	−2.8400	−3.78	400
500	4.2	35.2	1,480.9	−0.0125	−2.5000	−6.28	600
700	3.9	35.1	1,486.0	−0.0091	−1.8200	−8.10	800
900	3.7	35.1	1,491.8	−0.0052	−1.0400	−9.14	1,000
1,100	3.5	35.0	1,497.4	−0.0015	−0.3000	−9.44	1,200
1,300	3.3	35.0	1,503.2	+0.0024	+0.4800	−8.96	1,400

(a) Starting at a depth which approximates the draft of the transducers (2 fathoms in the example) or at a depth fixed by bar check, divide the first hundred fathoms into 5-fathom layers and enter in column (A) the mid-depth of each layer. Starting with 100 fathoms enter the mid-depth for each 20-fathom layer from 100 to 200 fathoms. For depths greater than 200 fathoms enter the mid-depth of 200-fathom layers.

(b) Scale the temperature and salinity values from the mean regional curves for the mid-depth of each layer and enter them in columns (B) and (C) respectively.

(c) Derive the velocity for each temperature and salinity and depth and enter the velocities in column (D). The velocities may be found from the tables in 7–28 or from the diagrams in 7–29.

(d) Derive the factors corresponding to each layer velocity and enter them in column (E). Table 17 gives these correction factors for velocities of sound to the nearest meter for instruments operating at three calibration velocities. For an instrument operated at any other calibrated velocity of sound, the factor can be obtained from the formula:

$$\frac{A - C}{C} = \pm \text{ factor}$$

in which A = actual mean velocity and C = calibration velocity.

(e) Multiply each correction factor in (E) by the layer thickness in fathoms to derive the correction applicable to this depth interval. Enter these products in column (F).

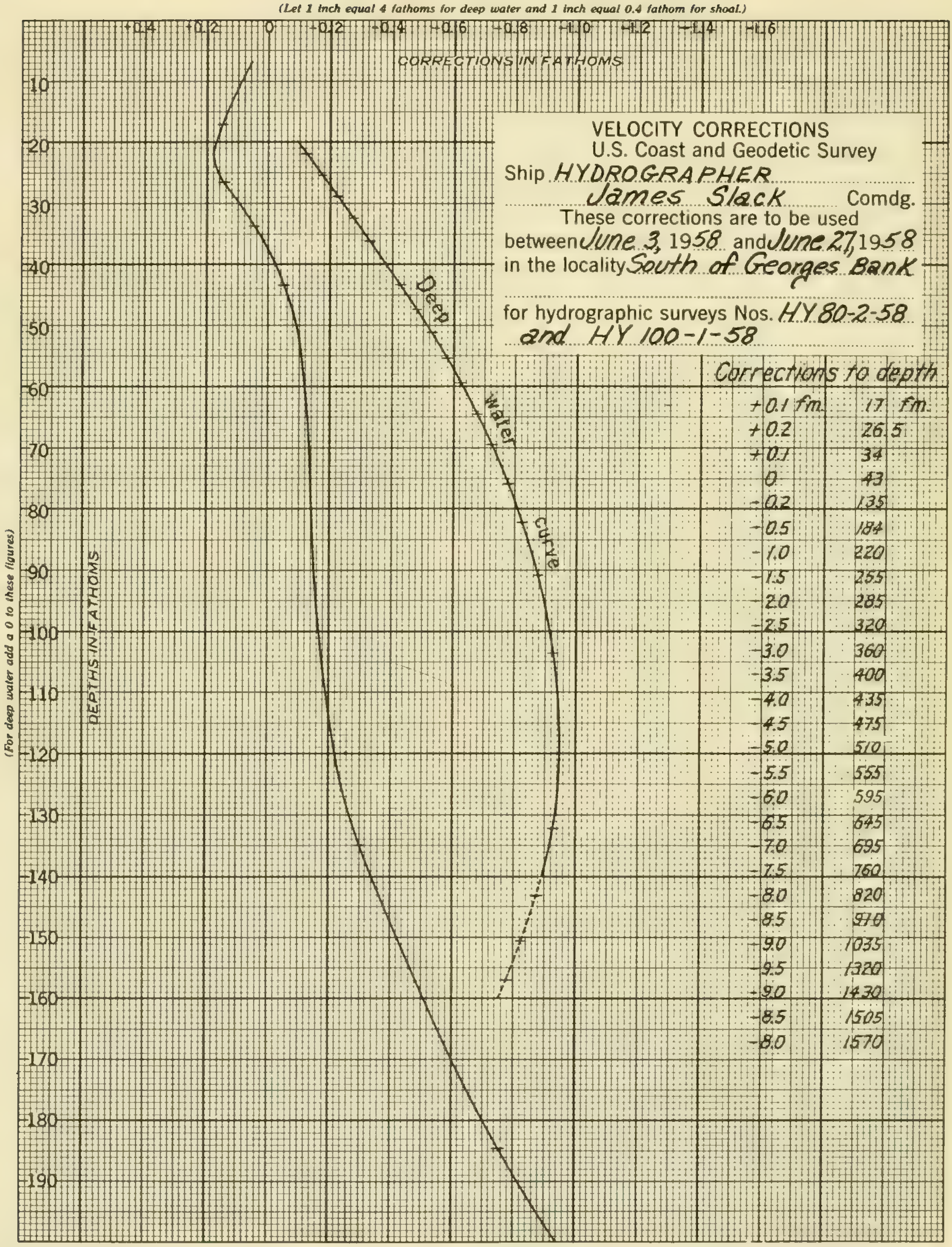


FIGURE 71.—Curve of velocity corrections to echo soundings, Form 117. (Reduced about one-third.)

(f) Add the values in column (F) algebraically and enter the progressive sums with their correct signs in column (G).

(g) For convenience enter in column (H) the depth of the bottom of each layer. This is the depth for which the entry on the same line in column (G) is the correction.

(h) The values in column (G) are then plotted on Form 117 with reference to the depths in column (H) to which they apply and a smooth curve is drawn through them. A table of corrections is compiled from this curve as shown in Figure 71. The units of the corrections depend on the depth and character of the area (see Table 2 and Section 5–101).

5–118 Graphic determination of velocity corrections.—Specially prepared velocity correction graphs are used in determining velocity corrections by the graphic method. Three graphs are available from the Washington Office for calibration velocities of 800, 810, or 820 fathoms per second and are identified by form numbers 117A, 117B, and 117C respectively. Form 117C is reproduced at a reduced scale in Figure 72.

The velocity correction graphs are designed for use directly with Form 117. They are constructed so that horizontal scales for the 20-fathom and 200-fathom layers correspond to the scales used on the above form. Where 5-fathom layer-intervals are used, the values taken graphically from the graphs must be divided by four to reduce them to the 20-fathom layer scale for use on Form 117. This can be done by using proportional dividers.

By use of a graph the velocity correction curve can be constructed directly on Form 117 from the temperatures and salinities in columns (B) and (C) of Table 11. The procedure is as follows:

(a) For depths of 200 fathoms or less.—Using the mid-depth of the first layer and corresponding temperature and salinity values, as in columns (A), (B), and (C) in Table 11, enter the appropriate correction graph with the temperature as an ordinate and find where it intersects the salinity curve for the corresponding salinity. With a proportional divider set to a ratio of 1 to 4, measure the distance from the intercept to index line of the graph, and transfer one-fourth of the distance to Form 117 in the proper direction at the bottom of the first layer. This gives one point on the desired velocity correction curve.

Proceed in like manner for the second layer, except that the intercept is added graphically to the distance already laid off for the first layer, always being careful to observe the sign of the correction. Transfer the resultant total distance to Form 117 at the bottom of the second layer.

Follow the above procedure for other layers until the entire depth range has been covered. Note that the one-fourth reduction is not made for 20-fathom layers. It is to be noted that no correction for pressure is included for depths less than 200 fathoms. Consequently there will be a slight, but negligible difference between curves derived by the two systems.

(b) For depths greater than 200 fathoms.—The use of the velocity correction graphs for depths greater than 200 fathoms is exactly the same as described above, except for an additional correction for pressure. Near the right-hand edge of the velocity correction graph is a diagonal line labeled "Pressure Correction Curve for 200-Fathom Layers." This curve is based on corrections computed for 200-fathom layers at the standard velocity of the graph, each correction being based on the mean depth of the layer; thus, the pressure correction of 4.8 fathoms (Fig. 72) read on the curve opposite 1,200 fathoms is the correction for the 200-fathom layer between 1,000 and 1,200 fathoms, computed for a mean depth of 1,100 fathoms.

For depths greater than 2,000 fathoms, a pressure curve can be readily constructed by transferring the intercept for 2,000 fathoms (at the bottom of the graph) to the top of the graph and drawing a line parallel to the printed pressure curve.

For the first point on the deep-water correction curve at 200 fathoms, scale the correction for 200 fathoms from the shoal-water correction curve already prepared and divide

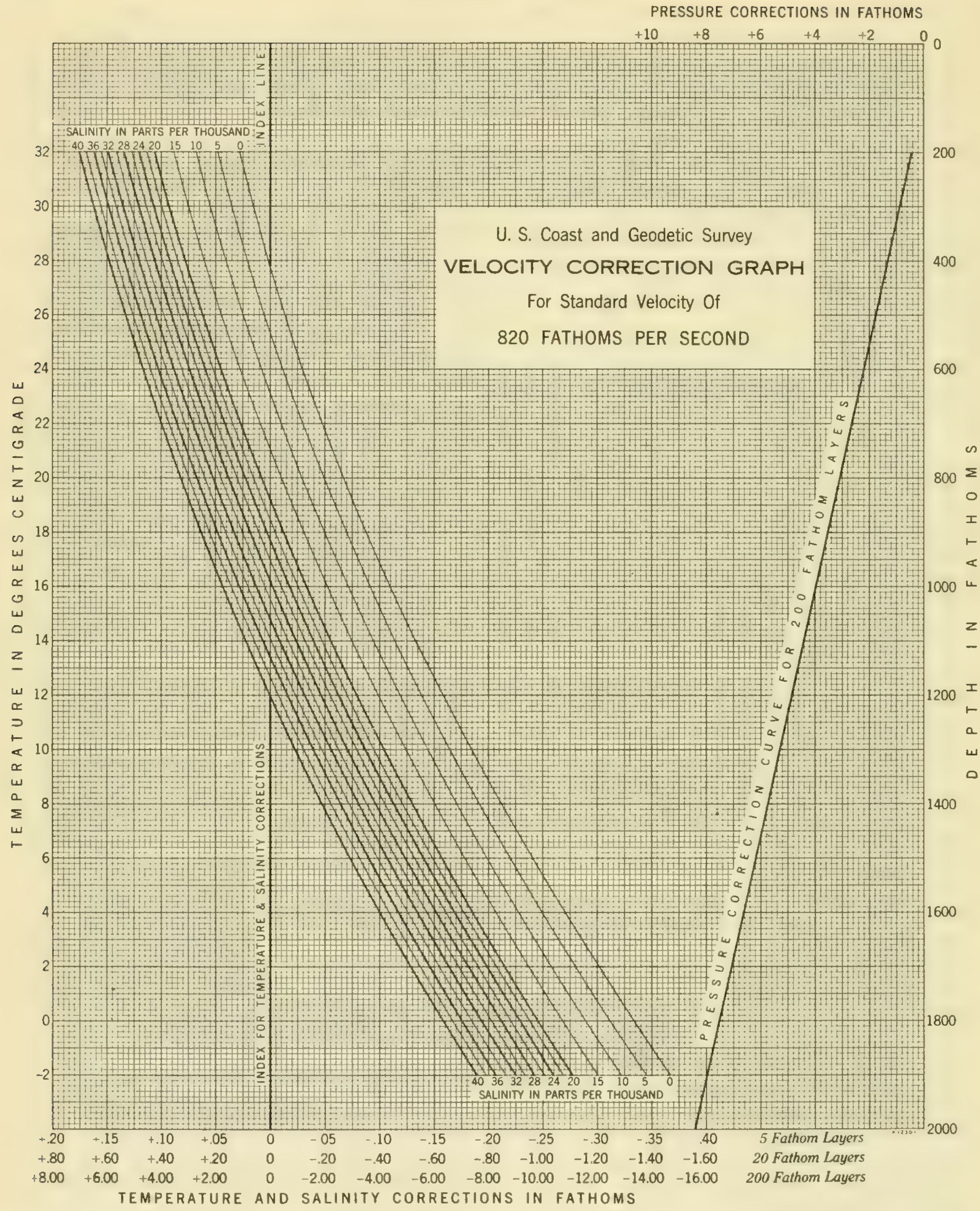


FIGURE 72.—Velocity correction graph, Form 117C. (Reduced about one-third. Do not use this figure to derive corrections.)

it by 10 to adapt it to the deep-water scale. Lay this distance off on the edge of a strip of paper, taking care to mark the correct end zero and the value of the correction with the correct sign (plus to the left and minus to the right). To this value apply graphically the correction at 200 fathoms from the pressure correction curve (it will be noted that all corrections for pressure are plus and should be applied to the left), transferring the resultant to Form 117 at 200 fathoms (deep-water scale).

Enter the velocity correction graph with the temperature and salinity for the mid-depth (300 fathoms) of the next layer, and apply in the proper direction the resulting intercept graphically to the previous distance on the paper strip. Then set the paper strip on the pressure curve at 400 fathoms and from the last mark on the strip apply the pressure intercept graphically. The resultant distance from the zero on the strip will be the distance to be laid off at 400 fathoms on Form 117.

Proceed in like manner for other layers to the deepest depth required.

The construction of a deep-water curve is simplified where it is possible to transfer the pressure correction curve from the velocity correction graph to Form 117. In such cases the corrections for temperature and salinity are laid off from the pressure curve as an initial, instead of from the zero of the velocity correction curve. As each point on the curve is plotted, its distance from the zero line of the curve must be marked on the strip of paper before the next intercept for temperature and salinity is added graphically to it, the total distance being laid off from the transferred pressure curve as an initial. An analysis of this graphic method of summation will make it clear why this must be done. Each horizontal distance plotted on the velocity correction curve in this manner must consist of the summation of all the corrections for temperature and salinity, and all the pressure corrections except the final one, the latter being accounted for by the transferred pressure correction curve. This possibility of utilizing the pressure correction curve should be kept in mind when fixing the zero of the velocity correction curve on Form 117.

(c) For shoal-water depths.—Where corrections in feet are desired, it is necessary to change all units from fathoms to feet on both the velocity correction graph and on Form 117. The corrections for 5-fathom layers printed at the bottom of the correction graph will then be in feet, and for 5-foot layers. Likewise, the horizontal scale of Form 117 will be 1 inch equals 0.4 foot, but the horizontal scale of the velocity correction graph will be 1 inch equals 0.1 foot. Therefore, each distance scaled from the velocity correction must be divided by four before being plotted on Form 117. This may be done conveniently by using proportional dividers to scale the intercepts.

When determining velocity corrections in feet, it will also be found convenient to prepare the temperature and salinity curves in feet instead of fathoms.

After the velocity correction curves have been determined, the procedure is the same as for the numerical method.

5–119 Velocity corrections by Velocimeter.—The velocity of sound in sea water can be determined *in situ* by use of the velocimeter described in 3–132. When this instrument is used, the observations are translated to velocity and a velocity curve related to depth can be drawn on any suitable graph paper. The layer velocities shown in Column (D) in Table 11, can be scaled from the velocity curve at the mid point of the layer. The correction factor is obtained by reference to Table 17 or can be computed. The procedure from this point is the same as for the numerical method of deriving the corrections.

The present stage of development of the velocimeter limits its use for this purpose to depths of about 500 feet. True depths of the various velocity measurements depend on the verticality of the cable used to suspend the instrument. Therefore, it should be used only under favorable conditions of wind, sea, and current.

5–120 Mechanical correction of velocities—The application of arithmetical corrections for differences between calibrated and actual velocities can be avoided when using the EDO–255 depth recorder under certain conditions. The frequency of the power supply can be varied to accommodate changes in velocity of sound in sea water over a range of about 4,600 to 5,000 feet per second (see 3–85). The procedure is as follows:

(a) Determine the velocity of sound to the maximum depth in the area to be surveyed, by velocimeter or from serial temperature and salinity observations, and draw a velocity curve. Determine the mean velocity for this depth range.

(b) Compute the frequency corresponding to the mean velocity and adjust the power supply to provide this reading on the frequency meter.

If the velocity at any point on the curve differs from the mean velocity by one-half percent or more, this system cannot be used without applying velocity corrections. The velocity curve must be determined with sufficient frequency to assure correct setting of the frequency meter. The frequency must be held constant and no attempt shall be made to vary the frequency during the day's work.

The paper speed (see 3–84 (i)) will change with change of frequency and by the same percent.

The adopted frequency shall be noted in the sounding record and the fact that such frequency is maintained shall also be noted. The descriptive report shall contain a full report on the procedure used.

Bar check requirements are not altered when this system is used, however the system will probably affect the results. The initial shall be set to compensate for draft of the transducer and instrumental error. The curve of actual velocity of sound will cross the vertical line representing the mean velocity adopted for sounding. A bar check at this depth of crossing should show a zero correction, and at other depths may show slight differences which may be disregarded provided that they are less than one-half percent of the depth.

5–121 Scanning fathograms.—Before soundings are plotted on the boat sheet (see 5–63) the hydrographer shall inspect the fathogram to assure himself that all important soundings have been scaled and recorded in the sounding record. As the soundings are plotted, he should verify any recorded sounding which appears doubtful when compared with other soundings on adjacent lines, or shows abrupt changes in slope which are contrary to the general characteristics of the area.

Some hydrographers make a complete review of the fathogram, check the recorded soundings, and record additional soundings as necessary, prior to plotting the soundings on the boat sheet. In many instances this is considered a final check of the scanning prior to the smooth plot of the survey. The advisability of this practice is questionable, since the checking is usually done rather hurriedly.

When the procedure described in the first paragraph of this section is followed, it is necessary to rescan the fathograms in detail at a later date and prior to the reduction of the soundings. This is a relatively simple operation for the majority of surveys, however the work must be done carefully and accurately by competent personnel. When the bottom is irregular or when the bottom trace is partially obscured by kelp, grass, strays, or side echoes a considerable amount of experience is required for proper interpretation of the record (see 5–122). Regardless of the character of the bottom, the fathogram may contain marks attributable to echoes from fish, debris floating at various depths, turbulence in the water, abrupt changes in temperature or density of the water, noises generated in the sounding vessel, or they may be caused by instrumental faults. Some skill is required in order that each trace may be correctly identified and the greatest value and the most accurate results obtained from the records.

The fathogram should first be examined to determine whether the initial trace has

varied by an amount sufficient to require correction and all necessary corrections should be entered in the record book at the appropriate places. If soundings have been obtained on more than one scale (phase) all changes of scale shall be correctly labeled on the fathogram and noted in the sounding record. If a template is used when scaling the soundings, the paper speed should be checked at each setting of the template. If a template is not used, several speed checks should be made at random during the day's work. If there is evidence of incorrect speed, a detailed examination is necessary to determine where corrections are required and their amounts.

The soundings should then be scaled at the selected interval and compared with the recorded soundings, correcting the latter when necessary. All significant peaks and deeps which occur between the soundings recorded at regular intervals shall be scaled and entered in the record book and the time or fraction of sounding interval recorded. When the bottom is very irregular and it is not practicable to scan or plot soundings to show every irregularity, soundings should be selected to show the general character of the bottom.

Poor scanning techniques, careless scanning, scanning by inadequately trained personnel, and improper interpretation are among the major causes of defects encountered in verification of smooth sheets. This phase of the processing shall be closely supervised and inspected in order that a high standard of accuracy may be maintained (see 1–34).

5–122 Interpretation of fathograms.—Although depth recorders have been used for many years, the correct interpretation of fathograms remains a major problem on many surveys. Where recorded traces on the fathogram cannot be attributed with considerable certainty to reflections from the bottom or from obstructions, they should not be recorded as soundings. Herein lies the principal source of difficulty, since there are occasional differences of opinion regarding the identification of such traces even among the most experienced observers.

The hydrographer should investigate a number of representative strays with a handlead in order to verify his interpretation of the fathogram. This procedure will not assure infallible interpretation of fathograms, but it will provide tangible evidence on which to base the interpretation.

In many areas, the depth recorder is an imperfect means of obtaining soundings and it should not be relied on as the sole depth measuring device. Supplementary handlead or pole soundings are required for clarification of certain traces, substantiation of doubtful least depths, and, in areas of dense grass, even for the basic development.

It is not feasible to illustrate all the varieties of traces which may appear on fathograms, but the following reproductions of fathograms are examples of typical records requiring interpretation.

Where strays are the result of erratic operation of the depth recorder or originate from other causes of which only the hydrographer has personal knowledge, they should be adequately annotated on the fathogram or in the sounding record. When the gain is too high, strays from various sources may be recorded on the graph and are generally identifiable as such (see Fig. 73A).

A section of the same fathogram is reproduced in Figure 73B. Note the unbroken bottom trace and the depression below the unidentified echo indicating a scour around a submerged obstruction. Subsequent wire-drag investigation revealed the presence of a wreck with kelp on top.

Kelp recordings probably cause the greatest difficulty in fathogram interpretation. Since kelp seldom grows in depths greater than 15 fathoms, difficulties from this source are encountered in relatively shoal water, and usually in areas of irregular bottom. The traces may resemble side echoes and be detached from the bottom trace as at (1) in Figure 73C or they may blend with the bottom trace as at (2). The bottom profile can usually be traced through the kelp by holding the fathogram at a slant to accen-

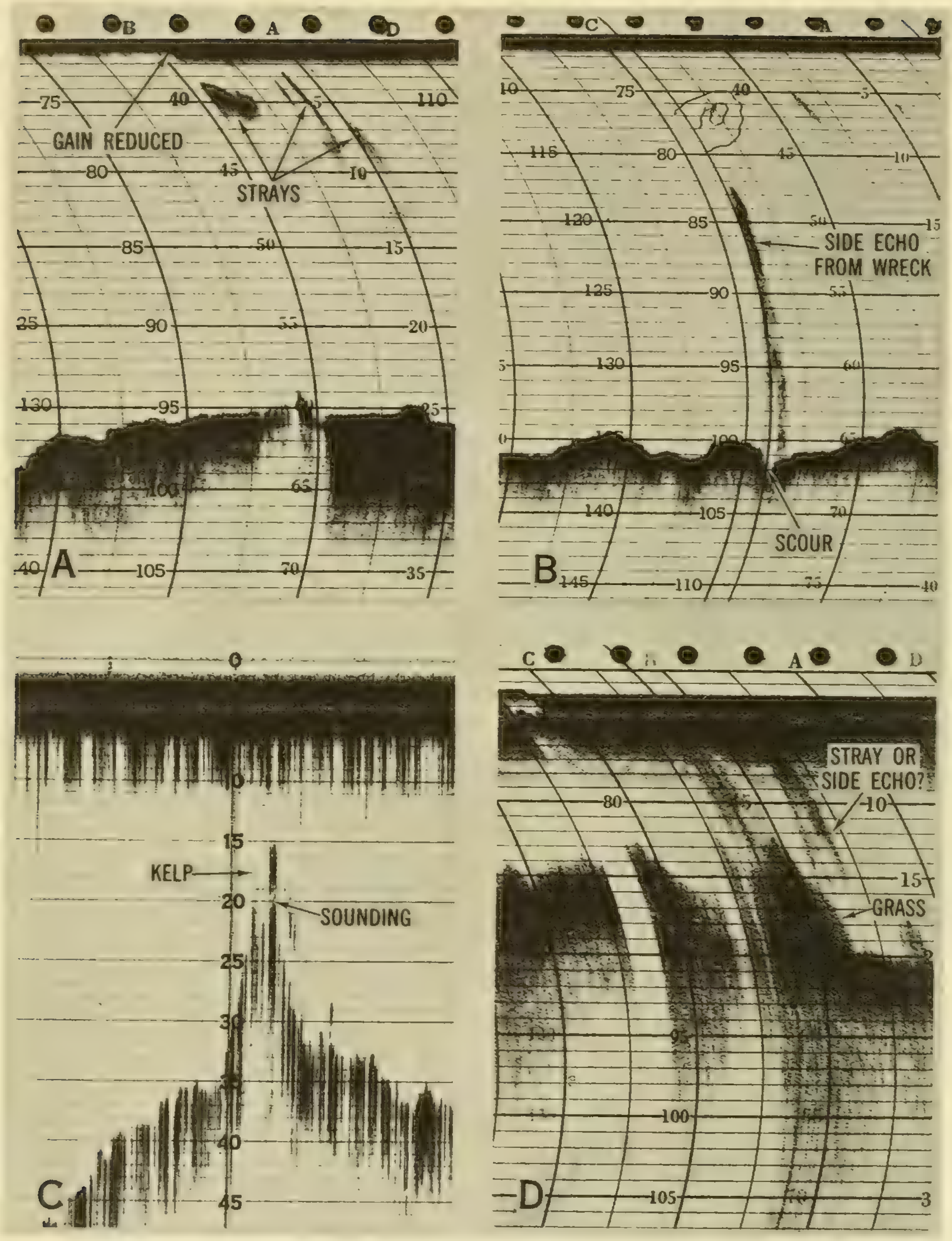


Figure 73.—Typical fathograms showing strays, side echoes, kelp and grass.

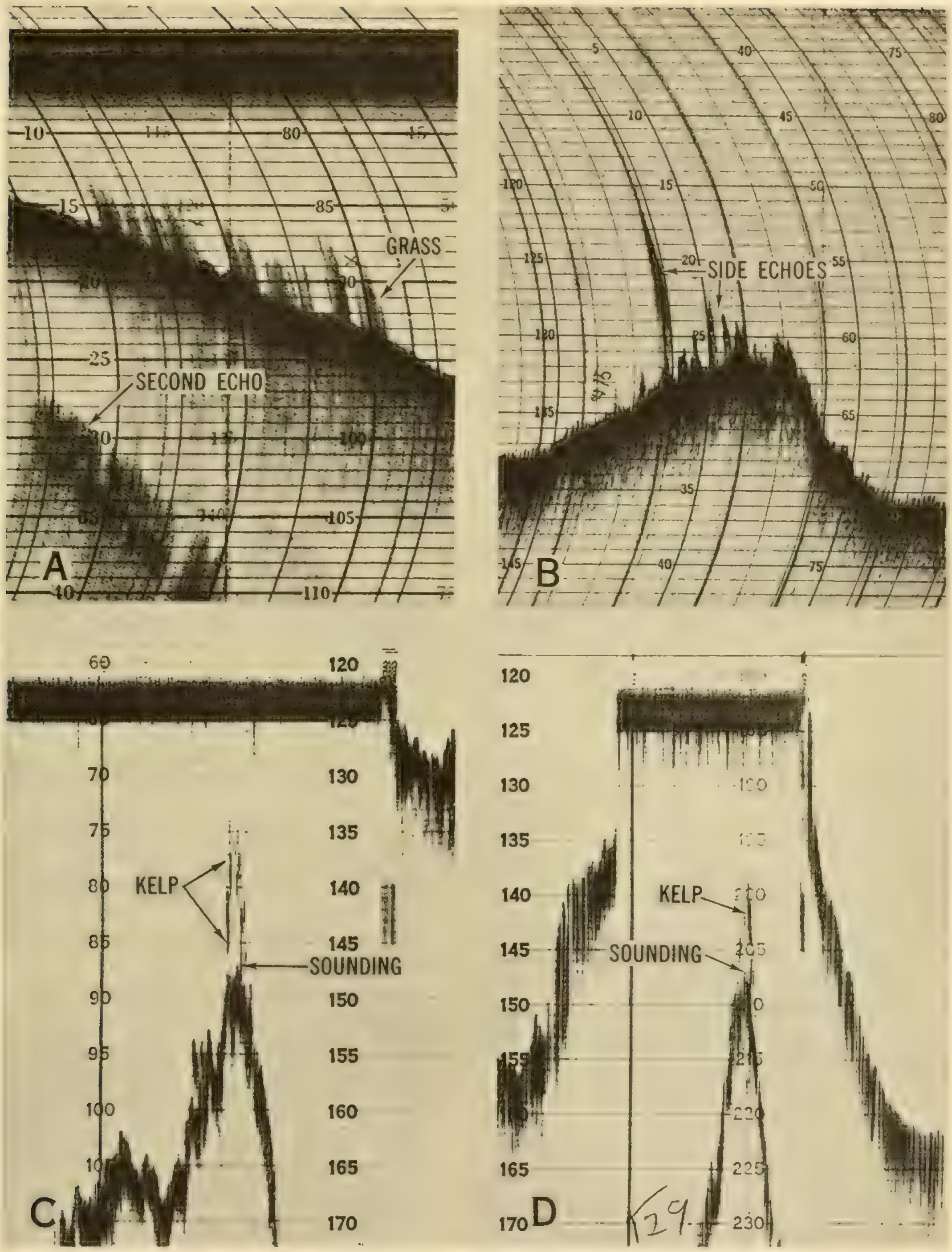


FIGURE 74.—Typical problems of fathogram interpretation.

tuate the differences in shading of the traces. Since it is not always possible to determine the line of separation, doubtful soundings should be investigated by a handlead. It is not practical to investigate all such soundings in a generally foul area, but the limiting features must be carefully sounded, and any indication of a pinnacle in or adjacent to a navigable waterway must be examined.

Difficulties of fathogram interpretation when kelp or grass is present, increase with increased transducer frequency. Echoes from kelp and echoes from the bottom are distinguishable on many 808 fathograms, but are considerably less discernible on EDO–255 records, and bottom echoes are completely masked when very high frequency transducers are used. In consequence more leadline or pole soundings are required to substantiate fathogram interpretation when transducer frequency is increased.

In areas of heavy grass the bottom trace may be completely obscured, as in Figure 73D. Usually the top of the profile will have a ragged appearance in contrast to the smooth bottom, however, in some instances the top of the grass will appear no more irregular than many ragged bottom profiles. In Figure 74(A) the bottom can be easily identified in the gaps between traces from the grass, and the bottom profile can be drawn with assurance. Unless a bottom sounding can be identified with sufficient frequency for a basic survey, supplemental leadline or pole soundings must be obtained.

Side echoes produce traces which may be detached from the bottom trace, blend with the bottom trace, or mask it completely. It is not always possible to distinguish between a side echo and echoes from fish or turbulent water. Occasionally a side echo is the only indication of a boulder, pinnacle, or other submerged obstruction. Side echoes should not be ignored, neither should they be recorded as true depths. Such soundings should be noted in the remarks column and, unless they come from previously identified shoaler features, additional lines should be run to obtain the least depth on them. Typical side echoes are shown in Figure 74(B). Where the side echo represents the shoalest depth obtained on an isolated feature, it should be accepted and plotted as the least depth thereon.

Irregular profiles resulting from swells or choppy seas are similar to profiles of sand waves. When the irregular profile is caused by sea conditions, readings should be taken along a line representing the mean depth, and not from the top of the peaks. The sounding record and fathogram should contain notes establishing the cause of the irregular profile. When this information is lacking, an examination of the fathogram will usually reveal the cause. Chop or swell will be apparent over the whole line, and the character of the graph will be changed when going with or into the sea.

5–123 Final reduced soundings.—After all check scanning of fathograms has been completed and all reducers entered in the sounding record and verified, the recorded soundings shall be reduced by the algebraic sum of the corrections and the corrected soundings, entered in the column headed "Field." These soundings shall always be entered in the same unit used for recording them, either feet or fathoms. Since only one unit may be used on a smooth sheet, it is sometimes necessary to convert recorded soundings to the unit to be used in plotting. The conversion shall be made as shown in Table 12 and the results entered in the double column headed "Office."

The reduction of soundings and conversions, if any, shall be checked. To indicate that this has been done, a check mark shall be placed opposite each verified correction entry and at the bottom of each column of reduced or converted soundings. The initials of the persons who made the original entries and of those who checked them shall be entered in the appropriate spaces of rubber Stamp No. 38.

Special Types of Surveys

5–124 Wire-drag surveys.—Wire-drag equipment and survey methods are described in the Wire Drag Manual, Publication 20–1.

TABLE 12.—Conversion of reduced soundings

Reduced soundings in Sounding Record		To be plotted on smooth sheet in —	Reduced soundings in Sounding Record		To be plotted on smooth sheet in —
Feet	*Fathoms*	*Feet*	*Feet*	*Feet*	*Fathoms*
−1.2 −0.3	−0.2 −0.1	−1		−0.7 −0.2	−0.1
−0.2 0.7	0.0 0.1	0		−0.1 0.4	0.0
0.8 1.7	0.2	1	1	0.5 1.0	0.1
1.8 2.7	0.3 0.4	2		1.1 1.6	0.2
2.8 3.7	0.5 0.6	3	2	1.7 2.2	0.3
3.8 4.7	0.7	4		2.3 2.8	0.4
4.8 5.7	0.8 0.9	5	3	2.9 3.4	0.5
			4	3.5 4.0	0.6
				4.1 4.6	0.7
			5	4.7 5.2	0.8
				5.3 5.8	0.9

In areas of rocky bottom or where submerged obstacles such as wrecks are present, the surest and most practical method at present of determining that all obstructions or dangers have been found and least depths over them obtained is by use of a wire drag.

Most wire-drag surveys will be accomplished by parties especially organized for that purpose. But survey ships should be equipped with a short wire drag which can be handled by launches in order that limited drag investigations can be made when necessary.

5–125 Reconnaissance surveys.—A reconnaissance survey is a preliminary survey of an area to obtain information in advance of a detailed survey. It may vary in character from few exploratory sounding lines with little or no control, to an extensive search of a channel or anchorage at an indefinite scale and only approximate relation to the adopted geodetic datum. The results of such a survey, if released, must contain a note indicating its quality.

5–126 Large-scale surveys.—It is occasionally necessary to make a hydrographic survey at a large scale, sometimes as large as 1:1,000. These surveys are usually intended to furnish detailed information for dredging or other types of harbor improvement. Sextant angles can be used to control surveys at scales as large as 1:2,500, but the control stations must be located precisely and the sextant angles must be marked simultaneously. To avoid distortion in the sheet, the survey should be plotted on aluminum mounted paper. For scales larger than 1:5,000, parallel ranges should be established along the shore. If a prominent object in the distant background can be seen throughout the area to be surveyed, it may be used as the rear range to a series of front ranges established along the shore.

For surveys of the greatest accuracy in river and harbor work the positions of the soundings are determined by theodolite or transit cuts from triangulation stations suitably situated. Two stations are sufficient to determine a position, but three are advisable to provide a check and to ensure that a position is obtained if one observer misses his observation. Ranges must be provided in order that straight parallel lines may be run. The soundings and position data must be coordinated by time as recorded at the launch and shore stations. The clocks must be compared frequently and corrected if necessary. The entire operation can be controlled at the launch if radiotelephones are used; otherwise the positions should be observed on signal from the launch. Soundings should be taken by pole when the depth permits.

Directions measured with the transits must be referred to a known direction or azimuth and the correct orientation with respect to the initial should be verified at frequent intervals. The directions should be read to the nearest half-minute.

The survey may be accurately controlled by stationing one shore observer at a control station with a theodolite or transit to observe a direction to the vessel at each position, while on board the vessel a sextant angle is simultaneously measured between two objects so located with reference to the occupied shore station that the circle defined by the locus of the observed angle will intersect the observed direction as nearly at right angles as practicable. The positions are plotted by laying off each direction line from the shore station and, with a three-arm protractor, plotting each sextant angle so that its vertex falls on the respective direction line.

If a series of equally spaced control stations are accurately located along the shore and successively occupied for measuring directions to the vessel, the shore observer can also direct the vessel on course when sounding lines are run toward and away from him, thus eliminating the need for ranges.

For still greater precision, it is generally necessary to stop the boat for each sounding at predetermined distances from the front range marks. For an accurate survey in the vicinity of a pier or wharf, equally spaced control points may be established by taped distances along the edge of the pier or wharf. The sounding lines are generally run normal to the line of control points although they can be run at any selected direction therefrom. The boat is controlled on line by an observer at the control point who marks its progress with a transit or sextant, signaling it from time to time to keep it on line.

Equally spaced soundings are generally taken at predetermined distances from the control points by direct measurement with a line (often referred to as a tagline), either marked at equal intervals or run over a registering sheave. Stranded sounding wire fastened to a ring or loop, marked at equal distances by white rags inserted in the strands, will serve admirably for this purpose. A reel should be provided by which to pay out or reel in the sounding wire. The zero end of the wire may be on the boat or at the control mark. If on the boat, a man is stationed at the control point with the reel; the boat proceeds slowly along the predetermined line and at the proper intervals it is stopped for soundings by braking the reel. If the zero end is at the mark, the reel is on the boat and the boat is stopped by a member of the crew applying the brake.

5–127 **Track or cruise lines.**—A continuous record of soundings obtained by a ship on an extended voyage en route between its home port and the working grounds is called a track line. The position of the line is fixed by the best available means and includes Loran observations, astronomic sights, and dead reckoning.

The proposed route should be laid down on a small scale nautical chart and carefully transferred to appropriate sheets in the H.O. 3000 (1–18) series of plotting charts at a scale of 1° Long. equals 4 inches. Standard methods of navigation, with some refinements, are used in an effort to follow the proposed route as closely as possible.

The beginning and ending of the line should be accurately fixed in position with reference to objects of known position. Three-point sextant fixes, cross bearings, or radar distances are acceptable in that order of preference.

5–128 **Standard Loran.**—When operating in areas served by Standard Loran systems, Loran lines of position should be observed once each hour. At least three lines of position should be determined when this is possible.

The range of Loran signals varies with time of day, location of the observer, static, amount of land between the observer and the stations, and ionospheric conditions. Signals may be received as ground waves or sky waves. The maximum range of ground waves is about 600 nautical miles during the day and 500 nautical miles at night. Usable sky waves may be received at a range of 1,400 nautical miles under the best possible conditions. As a general rule dependable Loran fixes can be obtained at distances somewhat more than half the above stated maximums, and accuracy of positions will decease as the distances from the stations increase.

The observer must always match similar waves, that is, ground waves or sky waves. A ground wave should never be matched with a sky wave. Only the first sky wave (one-hop E) should be used, and no pulse beyond this wave shall be used. The ground wave always appears first and the one-hop E wave second. If ground waves can be received from both stations of a pair, they should always be used. Sky waves are subject to variations in timing and changes of shape known as splitting and fading, caused by variations in the inosphere.

The position of the observer is determined by the intersection of two or more Loran lines of position. The Loran readings shall be recorded on Form 120 and a subscript "G" indicating ground waves, or "S" indicating sky waves shall be used in all cases. The line of position shall be computed from the data in the Loran Tables published by the Hydrographic Office. A line of position shall be advanced or retired if necessary to reduce all observations for a position to a specific time. All Loran computations shall be checked prior to submission with the records for the cruise.

5–129 **Astronomic observations.**—Astronomic sights are used to fix the position of a ship on track or cruise lines in a manner similar to their use in surface navigation, except that the sights are taken with greater precision and care, and they are used more accurately to control the line. The details of observation, computation, and use of astronomic sights are adequately described and explained in standard works on navigation, such as Bowditch (1958), Navigation and Nautical Astronomy—Dutton (1957), and Dutton's Navigation and Piloting—John C. Hill, II (1958), and need not be repeated here. The information in this manual is limited to refinements of observation and the best methods of using the data.

Form 719, or 719a, Astronomic Sight for Hydrographic Control, shall be used to record and compute all astronomic sights. Form 719 is arranged for use of the cosine-haversine formula, and Form 719a is designed for use with the Tables of Computed Altitude and Azimuth (H.O. Pub. No. 214). Any kind of astronomic sight may be computed on either form. For the most precise work, all computations should be worked to the nearest 0.1 second of time and to the nearest 0.1 minute of arc. All computations should be checked, the sheets bound in chronological order, and shipped to the Washington Office with the other survey records. Smooth copies are not required.

Astronomic observations should be made with navigating sextants, read to the nearest 10 seconds, and the time of each observation marked to the nearest 0.2 second using an accurate stop watch. When sea and sky conditions permit, each observer should make a series of 6 measurements to the star or other body being sighted upon. Each observer should have his own recorder.

Log readings or revolution counter readings should be recorded at 10-minute intervals during morning and evening star sight

observations. When star sights are taken from a vessel underway, the various sights must be advanced (run up) or retired (run back) to a selected dead-reckoning position.

Each observer's star sights shall be used independently to determine the probable position of the ship, after which the results may be compared and weighted if necessary and an official ship's position adopted. Observations taken by different observers, by different sextants, or at different times of the day should never be combined to determine a probable position. Each observer's sights should be plotted on separate sheets of paper. The dead-reckoning position, the adopted position of the ship, and the lines of position after being run up or run back should be inked. The name of each star observed and its direction should be indicated alongside each line of position. The observed lines of position and the distance and direction each was run up or back should be left in pencil. The adopted position should be transferred to the plotting sheet. If only one observer obtains the astronomic position, the final plot may be made on the plotting sheet (see 5–127).

There are several factors which influence the accuracy of astronomic observations. A change of 1 minute in altitude moves the line of position 1 nautical mile. At the Equator the altitude of a celestial body on the prime vertical changes 1 minute of arc in 4 seconds of time. For other latitudes and azimuths the error in position caused by an error in time is less, varying with the cosine of the latitude and the sine of the azimuth. All other conditions being equal, there is likely to be a greater error in an astronomic sight on a celestial body in an east or west direction than on one in a north or south direction. The reason for this is twofold: an error in time will affect the line of position proportionately more, and the bodies change faster in altitude making accurate observations more difficult. A distinct and clear horizon is essential for obtaining accurate observations. Evening star sights should be taken as early as possible, and morning sights as late as possible, to assure a well illuminated horizon. At the time of observation and not later, each observer should rate each set of sights, according to his opinion, "excellent," "good," "fair," or "poor." The rating should be based on consideration of the following factors:

(a) The relative distinctness of the horizon below each star observed.

(b) The disturbing effect of the roll and pitch of the vessel.

(c) The direction of the wind and whether or not it is blowing into the observer's eyes.

(d) The rate of change in altitude of the star.

(e) The relative distinctness of stars of different magnitude.

When the selected stars are symmetrically arranged and at approximately the same altitude, some of the errors of observation are partly eliminated in the final plot. Accidental errors of observation are not eliminated by this systemmatic arrangement. Only observations made by experienced personnel who are able to obtain rapid and consistently good results should be used. Inexperienced observers should be required to take and compute sights, but the results should not be used officially until they are known to be trustworthy.

For best results the celestial bodies to be observed should be selected so that lines of position will plot in a symmetrical quadrilateral. If more than four stars are observed, it is preferable to combine lines of position to a resultant rectangular figure of error whose sides are roughly north-south and east-west. The stars should be of about the same magnitude and about the same altitude. Observations on bodies at altitudes between 15° and 20° usually give best results, but altitudes between 10° and 35° may be considered satisfactory.

Due to the inherent inaccuracy of astronomic sights, the lines of position corrected for the run of the ship between sights usually do not intersect at a point. Three lines of position will form a triangle of error. The probable position of the ship derived from a series of morning or evening

star sights is based on the assumption that there is some type of error common to all the sights, approximately equal in amount and in the same direction with reference to the stars observed. It is not especially necessary that the amount of this error be small, but for best results it must be symmetrical. In determining the most probable position of the ship the directions of the observed bodies must always be considered. For unweighted observations the probable position should be equidistant from the lines of position and should lie either toward or away from each star of the series; never away from some and toward others.

There are two general methods which may be used to find the most probable position, and in a series of more than three or four sights a combination of these is preferable. The first method is to move all of the lines of position either away from or toward the objects observed by an equal distance to bring them as nearly as possible to a common intersection (see A and C in Fig. 75). In practice, it is not necessary to move the lines of position. The probable position may be found with the use of dividers, merely visualizing the transfer of the lines of position, but in this operation one must be certain to adopt a position which is on the correct side of each line of position considered; that is, it must be either toward or away from each star of the series.

The second method is to draw bisectrices between intersecting lines of position. Each bisectrix must be drawn so that it is either toward or away from the two objects observed. In a triangle of error formed by three lines of position the three bisectrices will intersect at a point, as in B, Figure 75. For four lines of position from stars in four directions two bisectrices should be drawn, each between two opposite lines of position, as in D, Figure 75. Where two opposite lines of position are from stars in the same direction, a mean line should first be drawn between them and this mean line and the other two lines treated as three lines and the bisectrices drawn as in B, Figure 75.

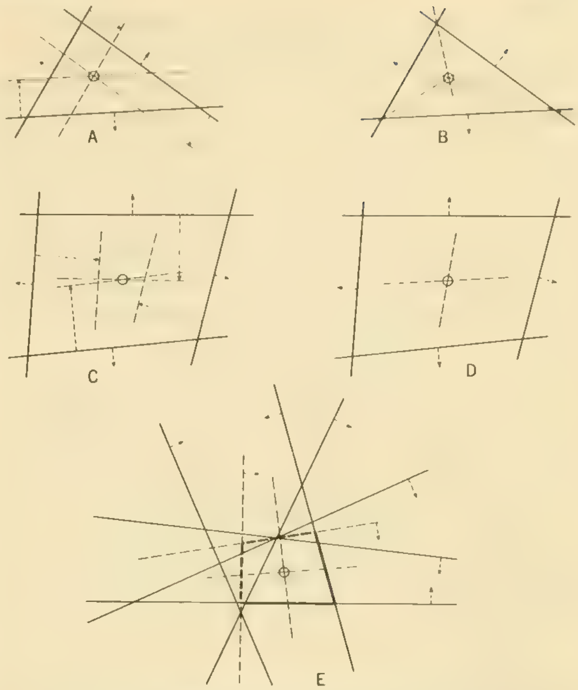


FIGURE 75.—Probable position of ship from stellar observations.

When more than four stars are observed in one series, the lines of position in the same general direction should be combined to reduce the data to not more than four lines of position. Assuming all observations to be of equal weight, the lines of position from two stars in the same general direction should be combined by drawing the bisectrix between them. From the figure of error thus formed the most probable position is determined as described above (see E, Fig. 75).

When the sun is visible, observations should be made on it at least five times a day. The first and last observations should be taken when the altitude of the sun is between 12° and 25°; the noon sight should be taken at local apparent noon, and the other two approximately halfway between the noon sight and the early morning and late afternoon sights. The meridian altitude sight should be taken independently by two or more observers. Individual sun sights should not be run up in the final plot, but shall be used as separate lines of position at the times of observation to which the line as a whole is adjusted.

5–130 Dead reckoning.—Dead reckoning is navigation by account, or reckoning, from the last known position. It is a procedure by which the position of a vessel at any instant is determined by applying the ship's run to the last known or well determined position, using for this purpose the course steered and distance traveled. Dead reckoning is used to plot track or cruise lines between fixed positions, and is frequently used to aid in evaluating EPI position data.

Dead reckoning is seldom exact, and the uncertainty of position increases in proportion to the distance from the last fixed position. Errors may be introduced in a number of ways. Those affecting the course include imperfect steering, incorrect allowance for compass error, leeway, and current; and those affecting distance are imperfect logs, unknown log factors, and incorrect allowance for current.

In order to attain greater accuracy a few refinements are applied to dead reckoning practices normally used in standard navigation. On a track line the engine speed should be maintained at a constant rate. On oceanographic cruises it is necessary to stop and lay to while making observations and the value of a constant rate of speed is diminished, but constant speed will be useful in making adjustments between fixed positions. The ship should be equipped with an accurately rated submerged electric log. The revolution counter should be read at all fixed positions in order that these readings may be substituted if the log fails to function properly. Courses must be steered very closely, within 1° if possible. When a gyropilot is not being used, only the most competent helmsmen should be assigned to steering duty. The officer on watch must check the course being steered at frequent intervals. The errors of any compass used must be accurately determined.

A complete record of events shall be kept on Form 722, Dead-Reckoning Abstract, as the line is run. On this abstract all control data should be entered which are to be used in plotting and adjusting the dead-reckoning line. It is particularly important that all entries be correctly related to time and that each event be recorded promptly. The data on the abstract, the Loran line of position computations, and the astronomic sights are used to make final adjustments of the plot.

Dead reckoning can be run most accurately in a dead calm, but this condition seldom exists. Experiments should be made to determine the amount of leeway which will be caused by winds of different velocities at various angles to the ship's heading. Graphs can be prepared from these data for use in estimating course changes to compensate for leeway.

An allowance must also be made for the set and drift of the current. In addition to oceanic currents encountered in many areas, a persistent wind will generate surface currents. An estimate of the wind-driven current may be based on the following:

(a) Observations have demonstrated that a persistent wind will set up a wind-driven current with a velocity of approximately 2 percent of that of the wind. This ratio can be expected to hold both in coastal areas and in the open ocean.

(b) The direction of the wind-driven current in the Northern Hemisphere has been found to be about 20° to the right of the wind in coastal areas, but theoretically this deflection is probably nearer 40° to the right of the wind in the open ocean. The rule for coastal wind-driven currents is not always applicable, especially near the shore where the direction of the current depends on the angle between the wind direction and the coastline.

The dead reckoning should be corrected for all known factors affecting course and distance before it is plotted. The difference between the dead reckoning position and the position determined by astronomic or other fix is the dead-reckoning closure. This difference is adjusted by distribution in proportion to time between fixed positions in the same manner as a traverse adjustment is made with respect to distance. This may not be a straight line adjustment, since sun sights, Loran lines of position, or other recorded data must be considered and eval-

uated in order to determine the most probable track of the vessel between fixed positions. Supplemental data which are obviously in error should be rejected on the abstract. The soundings along the track should be compared with the charted soundings. This comparison may give some assistance in the final adjustment.

6. THE SMOOTH SHEET

6–1 Definition and purpose.—A smooth sheet is the final, carefully made plot of a hydrographic survey. In contrast to the boat sheet, which is a work sheet plotted during field operations from preliminary field data, the smooth sheet is plotted from corrected data and conforms with more rigid cartographic standards which are described in this chapter.

After registry, verification, and review in the Washington Office, the smooth sheet becomes the official permanent record of that particular survey and is the principal authority for hydrographic data to be charted. The boat sheet is usually discarded after final administrative approval of the survey.

6–2 Smooth sheet paper.—Smooth sheets shall be prepared only on first-quality white drawing paper mounted on muslin furnished by the Washington Office in flat sheets. Plastic and aluminum mounted sheets are widely used in various activities, but they shall not be used for smooth sheets unless specifically authorized in project or other instructions.

Factors which control selection of suitable smooth sheet material are: minimum dimensional change (distortion), absence of surface imperfections, reception to inking particularly after erasure, toughness of a moistened surface, and pliability. Samples of smooth sheet stock are subjected to test before a shipment is accepted, however, considerable variation in the quality of smooth sheet paper is found even in the same shipment. If the paper is found to be unsuitable for smooth sheet plotting, the Washington Office should be notified of the particular fault or faults. The trade name of the paper and the date of receipt should be stated if these are known.

The most troublesome characteristic of muslin-mounted paper is the uneven distortion which occurs with changing temperature and humidity. Uniform distortion of a sheet presents no serious problem, but acceptable distortion should never be as much as 0.5 percent, and greater distortion is considered excessive. Although the best quality of smooth sheet paper is manufactured so that the percentage of contraction or expansion is nearly equal in all directions, tests have shown that distortion across the width of the paper usually is greater than for an equal distance lengthwise of the paper. The inequality of distortion in the two dimensions should not be as much as 0.25 percent.

In all plotting the amount of distortion should be determined and checked from time to time. Distortion should be compensated for as much as possible. In some instances it may be necessary to defer plotting until an unequally distorted projection returns to within reasonable limits.

Tracing cloth shall be used when it is advisable in a congested area to smooth plot supplemental hydrography separately for insertion in the descriptive report.

6–3 Smooth sheet sizes.—The standard size of a smooth sheet is 36 by 54 inches which shall not ordinarily be exceeded (see 1–8 and 2–22). Although sheets are furnished in 60-inch lengths, they should be trimmed to 54 inches unless the increased length is needed for plotting the control. When the entire sheet is not needed for the survey, any excess length over 8 inches at either end of the sheet should be trimmed off; however, the minimum dimension of the sheet shall not be less than 30 inches.

When oversize sheets are required to plot the sheet at the scale of the survey, consideration should be given to using a smaller scale as explained in 6–7.

6–4 Sheet margins.—In determining sheet sizes and limits of hydrography it is essential that soundings shall seldom be closer than about 3 inches to the edges of the sheet (see 2–20). By following this procedure the marginally plotted soundings will not become impaired or destroyed later because of repeated handling of the sheet.

6–5 Sheet extensions.—A limited area extension of a smooth sheet, referred to as a "dog-ear," (Fig. 76) is occasionally necessary to include a control station located beyond the edge of a sheet (see 2–24). This dog-ear appendage, which shall not extend more than 6 inches beyond the edge of the sheet, shall be firmly attached with strips of masking tape applied to the undersides. When the station is plotted on the dog-ear three fine inked lines, annotated with the station name and symbol, shall be drawn at the same time inside the edge of the sheet

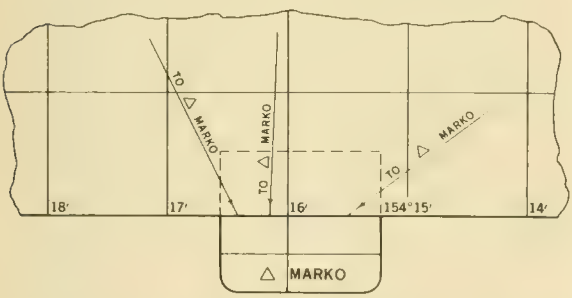


FIGURE 76.—Temporary extension for smooth sheet.

at sufficient angles and lengths that, if necessary, the station can be relocated after removal of the dog-ear. The necessity for use of dog-ears can be minimized by using great care in laying out the sheets (see 1–7 and 2–20).

6–6 Insets and subplans.—Smooth sheet insets and subplans are used to extend the survey coverage shown on one sheet, and to combine contemporary small detached surveys on the same project (see 2–23). Small congested areas shall be shown at enlarged scales in subplans in otherwise blank spaces on the smooth sheet where practicable (Fig. 77). The scale and extent of the subplan shall be large enough to show the hydrography clearly and to include the stations used to control the hydrography.

Enlarged subplans, such as those to include the water area of a small bay, cove, inlet, or anchorage area, shall be surrounded by a heavy margin in black ink. Each subplan must include the scale, name of the water area, if any, and at least one meridian and parallel. The area of the subplan should be identified in its true position by a fine dashed pencil outline and an arrow leading to the subplan. Details shown in the enlargement may be omitted from the original scale.

Where soundings are taken in small docks and along the sides and ends of small piers and are located by reference distances to or along the piers, enlarged plans of these (Fig.

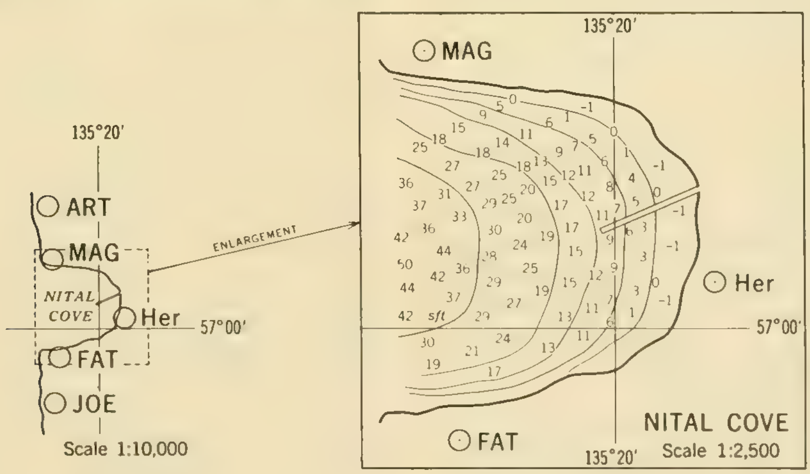


FIGURE 77.—Subplan of small cove on smooth sheet.

83) shall be shown nearby with arrows pointing to the area on the original scale plot. Such plans need not contain a scale or be surrounded by a margin. Each plan shall show in figures the principal dimensions of the pier.

6–7 Smooth sheet layout and scales.—The smooth sheet will generally duplicate the boat sheet in area coverage, orientation, and size. It is sometimes constructed concurrently or the boat sheet may also be the smooth sheet (see 1–10 and 6–45). At times it is advisable to modify the original sheet layout when unforeseen factors are introduced during field operations. Most of these factors are discussed in 6–4, 5 and 6.

The scale of the smooth sheet will generally be the same as that of the boat sheet, but in some cases it is desirable to use a smaller scale in order to reduce an oversize boat sheet, to eliminate an undesirable skewed projection, or to combine two adjacent surveys. Authority to plot a survey at a reduced scale must be obtained from the Director (see 2–19). Such reductions will be authorized: (a) when the smaller scale will not significantly detract from the value of the survey; (b) where charts at a larger scale are not contemplated; and (c) where the hydrography has revealed no shoals or submarine features which cannot be adequately shown at the reduced scale or on subplans or overlays.

Large scale smooth plotting is generally confined to subplans described in 6–6.

6–8 Preparation and protection.—The smooth sheet shall be allowed to cure or become conditioned to its plotting environment for as long a period as is practicable before the projection is drawn. Each sheet should be laid out or hung up separately where it will be completely exposed to the air on both sides for at least a few days before use. For best results the period of seasoning should embrace a wide variation of temperature and humidity. If the sheet cannot be seasoned by laying it flat, it should be suspended from successive edges and subsequently laid flat for several days. It shall be kept flat at least until completion of the projection and, if applicable, the checking of concentric control circles. The sheet may then be rolled loosely, if necessary. However, it is best to keep the sheet flat until all plotting is completed. When it is not being used, the sheet should be covered by a suitable protective canvas or other table cover.

The sheet shall be protected at all times from creasing, defacing, or smudging. All parts of the sheet should be kept covered except the small area on which work is actually being done. It is equally important to avoid indentations made by using sharp pointed or chisel-edged hard pencils. Temporary notes should be made lightly with a 3H pencil so that they may be erased without damage to the paper.

6–9 Check of drafting instruments.—The drafting instruments used in smooth plotting are subject to imperfections and should be tested before and during use (see 3–18, 21, 137 to 140). Some may be corrected by adjustment, others by applying calibration corrections, and others only by repair. Imperfect or unadjusted instruments may result in serious inaccuracies in the smooth plot. Particular attention is required to check plastic protractors as they may warp while in use.

6–10 Projection.—Procedures for construction of a projection are described in Sections 1–12 and 5–6, 7, and in Special Publication No. 5. The smooth sheet projection should be constructed with more care than is required for a boat sheet.

6–11 Circle lines of control.—Concentric circles or segments of circles representing distances or corresponding time intervals used in plotting electronically controlled hydrography shall be drawn soon after the projection has been completed in order to avoid distortion problems. The technique of positioning and drawing the circles is described in Sections 5–11 and 12, and in Coast and Geodetic Survey Journal No. 3, 1950. Each series of circles shall be identified by a distinctive color. Contrasting colors should be used, however yellow and orange colors

should not be used. The lines should be fine and solid and not more than 0.2 mm wide.

If the point of origin is within the limits of the sheet, it shall be symbolized by the appropriate station symbol and a 5 mm circle of corresponding color (Fig. 79). If the point of origin is off the sheet, the station name should be added to several of the circles or in a legend on the sheet.

The distance or time interval represented by each circle shall be shown in ink of a corresponding color with numbers about 2.5 to 3.0 mm high, and shall be positioned in otherwise blank areas of the sheet, if possible.

Circles of equal angle are sometimes used to plot sextant controlled hydrography (see 5–13). When required, these circles should also be drawn soon after the projection is made. The same principles apply with regard to colors used and identification of the stations and angles.

6–12 Quality of drafting.—The approved smooth sheet is the final graphic record of an engineering survey; an official government document which is retained permanently in archives of the Bureau. It is frequently referred to after use in chart compilation and photographic copies, often at a one-half reduced scale, are furnished to surveyors, engineers, geologists, and others, including lawyers for use in courts. It is evident, therefore, that the standard of accuracy for smooth plotting and detailing and also the clarity and neatness of the drafting should reflect the high standard of accuracy of the data plotted. The drafting should not be artistic; it need not be expert; it shall be neat, clearly legible and in accordance with the standards adopted for hydrographic smooth sheets as specified in this chapter.

6–13 Character of lettering.—Mechanical lettering sets or guides shall be used for lettering all names and numerals except position numbers, soundings, buoy designations, and rock elevations. In general, descriptive notes should be in freehand lettering (Fig. 82).

6–14 Orientation of lettering.—The lettering and symbols shall generally be aligned with the parallels of latitude so as to be read from the south. Where geographic names cannot be lettered on an east-west line, they shall be aligned at an angle or on a curve so that they can be read from the south (see 6–72).

Regardless of the direction of the sounding line, the individual soundings shall be consistently oriented normal to an east-west projection line, except in deep water where it may be necessary or advisable to plot 3- or 4-digit soundings at an angle. In such cases, orientation of these soundings shall be as consistent as possible and they should be easily read from the south (Fig. 84).

Both vertical and slant lettering are used on the smooth sheet. The names of topographic features, which in general are the names of everything above mean high water, shall be vertical letters. The names of hydrographic features, and in general all features below mean high water, shall be lettered in slanting letters. All numbers including position numbers and soundings shall be vertical, except that elevations of bare rocks and rocks awash shall be slanting numbers. Official names and designations of aids to navigation either ashore or afloat shall be lettered with slanting lines. Descriptive notes pertaining to all hydrographic features awash or covered at mean high water shall be lettered with slanting lines.

6–15 Placement of lettering.—Control station names and most other lettering shall be placed in the land areas in order to provide maximum clarity of hydrographic detail (see 5–10). Wherever practicable, station names should be on line with the bottom of the station symbol and separated from it by the space of one letter (Fig. 79). There should never be any doubt as to the name of a station. Where it is necessary to place a name so far away that doubt may arise as to its reference, a fine inked arrow or leader, in the same color as the name, should be drawn from the name to the symbol (Fig. 82). A large number of offset names, descriptions and designations is undesirable.

Station names should never be placed in the water area if it is possible to avoid it; however, an unimportant sounding, especially in flat areas, may be omitted to provide space for lettering if necessary. Where there is room for only the hydrographic signal name, this is lettered and the full station name together with the hydrographic name is lettered in an unused part of the sheet. Where the hydrographic detail is too congested to permit these normal identifications, a capital letter (A, B, C, etc.) may be used for reference to the full name placed in an unused part of the sheet. Arrows can be used to offset names and descriptions provided they are not too long and do not cross congested hydrography. The arrows should be broken when they cross a sounding.

6–16 Selection and use of pencils.—The use of proper drawing pencils is essential for good drafting. Pencils which are too hard may cut the surface of the paper, and lines from such pencils are often too dim to provide adequate photographic copy. The point of a soft pencil soon becomes blunt and often results in smearing the sheet with a layer of graphite which inhibits proper penetration of ink into the surface of the paper. Inked soundings deteriorate rapidly on a graphite-coated sheet.

A 3H or 4H pencil should be used for most work on a smooth sheet. The degree of hardness will vary as much as one grade in different brands of pencils but is usually consistent in each brand. Chisel-edged 5H pencils should be used for constructing the projection and for plotting triangulation stations by *lightly* drawing intersecting dm. and dp. lines. A hard chisel-edged pencil should not be used to delineate the sounding line as a guide for plotting soundings. No pencil line should be drawn so firmly that a permanent indentation is made in the paper because this may result in rupturing the sheet at the most critical places. Consideration should be given to variations in the surface of the paper caused by variations in humidity. See Table 13 for schedule of penciled and inked details on a smooth sheet.

6–17 Selection and use of ink.—The work of inking the survey properly is important. When completed it is the permanent

TABLE 13.—Schedule of penciled and inked details

	Smooth plot	*After office verification*
Projection and geographic values	Black	
Triangulation and topographic control symbols and names	Red	
Hydrographic control symbols and names	Blue	
Stations transferred directly from aerial photographs, and names	Green	
Circle lines-of-control	Selected colors	
Completion of Stamp No. 42	Black	
Landmark symbols and names	Black	
Descriptive notes at stations and topographic features	Pencil	Black.
except at aids to navigation	Pencil	Red.
Tide and current stations	Blue	
Shoreline from final or advance manuscript	Black	
Shoreline revised by hydrographer	Red	
Low-water line from topographic survey	Pencil	Black.
Limit lines of foul areas, breakers, kelp, etc.	Pencil	Black.
Ledge and reef	(a) Pencil	Black.
Rocks and their elevations	See Fig. 81	
Aids to navigation not used as stations	Pencil	Black, red.
Hydrographic position identifications	Selected colors	
Lines connecting hydrographic positions	Pencil	
Soundings	Pencil	Black.
Depth curves (Tables 3 & 4)	Pencil	Selected colors.
Bottom characteristics	Pencil	Black.
Marine vegetation of any kind	Pencil	Black.
Other hydrographic features—piles, stakes, wrecks, etc.	Pencil	Black.
Geographic names	Pencil	Black.
Junctions		Selected colors.
Wire-drag soundings (after Review)		Green.
Data from prior surveys (after Review)		Selected colors.

(a) Ink black where unaffected by hydrography.

graphic portrayal of the survey and it should reflect the care involved in obtaining and compiling engineering data. The standard character of inked lettering is indicated in Fig. 82. Freehand and mechanical pens shall be carefully selected and used to conform generally with these standards. The experienced draftsman is familiar with the various types of pens available and acquires proficiency with a selected few. A less experienced draftsman should experiment with different types of pens and practice lettering until he is able to produce acceptable work. The quality of ink work may be improved by tests of pen points and by gently smoothing, rounding, or sharpening the points with fine crocus cloth or oilstone when necessary. A set of pens for various colors is desirable to avoid blending of colors.

The quality of the ink used is very important. Improper selection of ink can result in faint, non-photographic, or watery detail which becomes more illegible with age. Bottles of coagulated or otherwise aged inks should be discarded. Waterproof drawing inks shall be used and pigmented inks should be stirred or shaken to homogeneous consistency before use. Some inks may need to be thickened slightly in order to eliminate the tendency of thin ink to spread into the fibers of the paper. This can usually be accomplished by natural evaporation on exposure to the air. The intensity of the color should be observed and new ink used when colors become weak. Green ink is particularly perishable and deteriorates rapidly.

Special inks shall be used on plastic materials to which ordinary waterproof drawing inks will not bind. It may be necessary to use a thinner with such ink, or to thicken it by normal air evaporation.

6–18 Erasures.—During the construction, plotting, and inking of a smooth sheet every effort should be made to minimize the use of erasers which roughen the paper and cause undesirable spreading and fading of ink work. Unused parts of a smooth sheet should be shielded to prevent unnecessary soiling and subsequent erasing. Soft erasers should be used when erasing becomes necessary. Ink erasures cannot be made without some damage to the surface, but less damage is generally caused by skillful use of an electric eraser than by any other method. Hard abrasive erasers should never be used, even for removal of ink work. With due care and a light touch a smooth inkable surface can be retained.

6–19 Control stations.—After the projection has been made and verified, the next step is plotting of the control stations. Only those stations used for control shall be plotted. Each station shall be plotted with extreme accuracy, and within 0.15 mm of its true position. The necessary accuracy of critical detail on a hydrographic survey depends to a large extend on accuracies in the horizontal control. The actual station point shall be a fine needle hole which is blackened but not enlarged by carefully rotating a sharp pencil point in the hole. Never use ink for the station dot. Plotting procedures depend on the nature of the control.

It is important that the plotted stations be carefully and accurately verified before plotting topographic detail and hydrography. Both the plotter and verifier shall record the actions by initialing in the lower right corner of the smooth sheet, on Stamp No. 42, Hydrographic Survey (Fig. 50). Neither person should proceed until the projection is verified and this action recorded. Should the record be incomplete on receipt of the smooth sheet in the Washington Office, it will then be necessary to verify the plotting before proceeding with verification of the hydrography.

Provision is also made in Stamp No. 42 to record the horizontal datum used in the survey, including the name, date, and geographic position of one of the triangulation stations plotted on the sheet.

6–20 Triangulation stations.—Triangulation stations are always plotted from the computed values of latitude and longitude. The meridional differences (dms.) along adjacent meridians and the parallel differences (dps.) along adjacent parallels are

plotted with a beam compass and metric scale. Dividers can be used for short distances, but they become less accurate when they are spread appreciably. The dm. and dp. distances in meters shall be marked by fine prick points adjacent to each set of projection lines and connected by fine pencil lines discussed in 6–16. As a check of the plotting, and to compensate for any possible distortion, the back dms. and dps. must also be plotted from the north parallel and west meridian (Fig. 78). In the event there is distortion, it shall be proportioned between the parallel dm. and parallel dp. lines. The position of the station at the intersection of the final dm. and dp. lines is marked as stated in 6–19. It is symbolized by a red equilateral triangle, 4.5 mm. on a side with base parallel to the lines of latitude and the station name is inked in red (Fig. 79). The symbol is readily formed in pencil by using a thin plastic template having the cut-out triangle and inked lines for orientation, or by drawing the sides tangent to a 2.6 mm. circle. Before inking, the triangulation point shall be verified by the same method or by use of special latitude and longitude scales.

6–21 Topographic stations.—Reverse blueline prints of photogrammetric compilations are furnished on stable plastic material for use in transferring topographic stations and shoreline detail to the smooth sheet (see 4–10 to 15). Before transferring a station point, a proportional adjustment must be

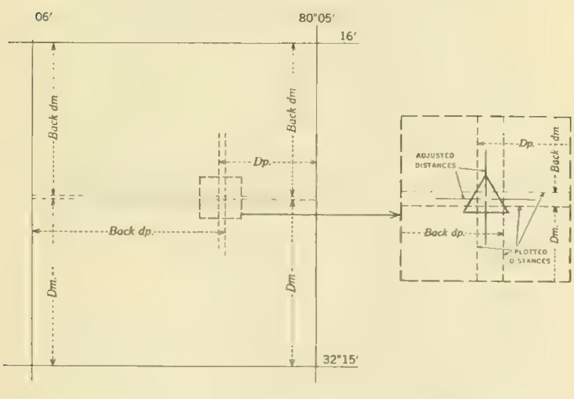


FIGURE 78.—Control station plotted by dms. and dps. on a distorted sheet.

made to compensate for any difference between the projections.

Stations located by planetable methods shall be transferred to the smooth sheet by pricking through a tracing of the topographic or graphic control sheet. The same care is required to adjust differences in the projections. Stations may also be transferred by use of dividers or a beam compass.

Topographic stations are symbolized by red circles 3.0 mm in diameter (Fig. 79), and the station name is inked in red. Stations which have been marked by a standard topographic disc shall be indicated on the sheet by the letter "m" in parentheses, (m), in black ink.

6–22 Hydrographic stations.—Hydrographic stations are those located by sextant fixes or cuts (see 4–26). They shall be carefully replotted on the smooth sheet. If there is distortion in the sheet, or if stations are considerable distances away, the position should be computed and the station plotted by dms. and dps. The index of the sounding volume should be carefully inspected to be certain that all available data are used to determine the correct position of the station. Such stations are symbolized by blue circles 3.0 mm in diameter and the station names lettered in blue (Fig. 79).

Where the position of a hydrographic station is subsequently determined by topographic or photogrammetric methods, the station shall be plotted and symbolized as in 6–21.

6–23 Supplemental stations.—Supplemental stations are sometimes established during progress of hydrography by spotting on the boat sheet a point which has been identified on a topographic map or air photograph. Unless such points are located later by other methods, they shall be symbolized by green circles 3.0 mm in diameter and the station names inked in green (Fig. 79).

6–24 Station names.—Station names on the smooth sheet must always agree with those on the boat sheet, the topographic sheets or photogrammetric compilations, and

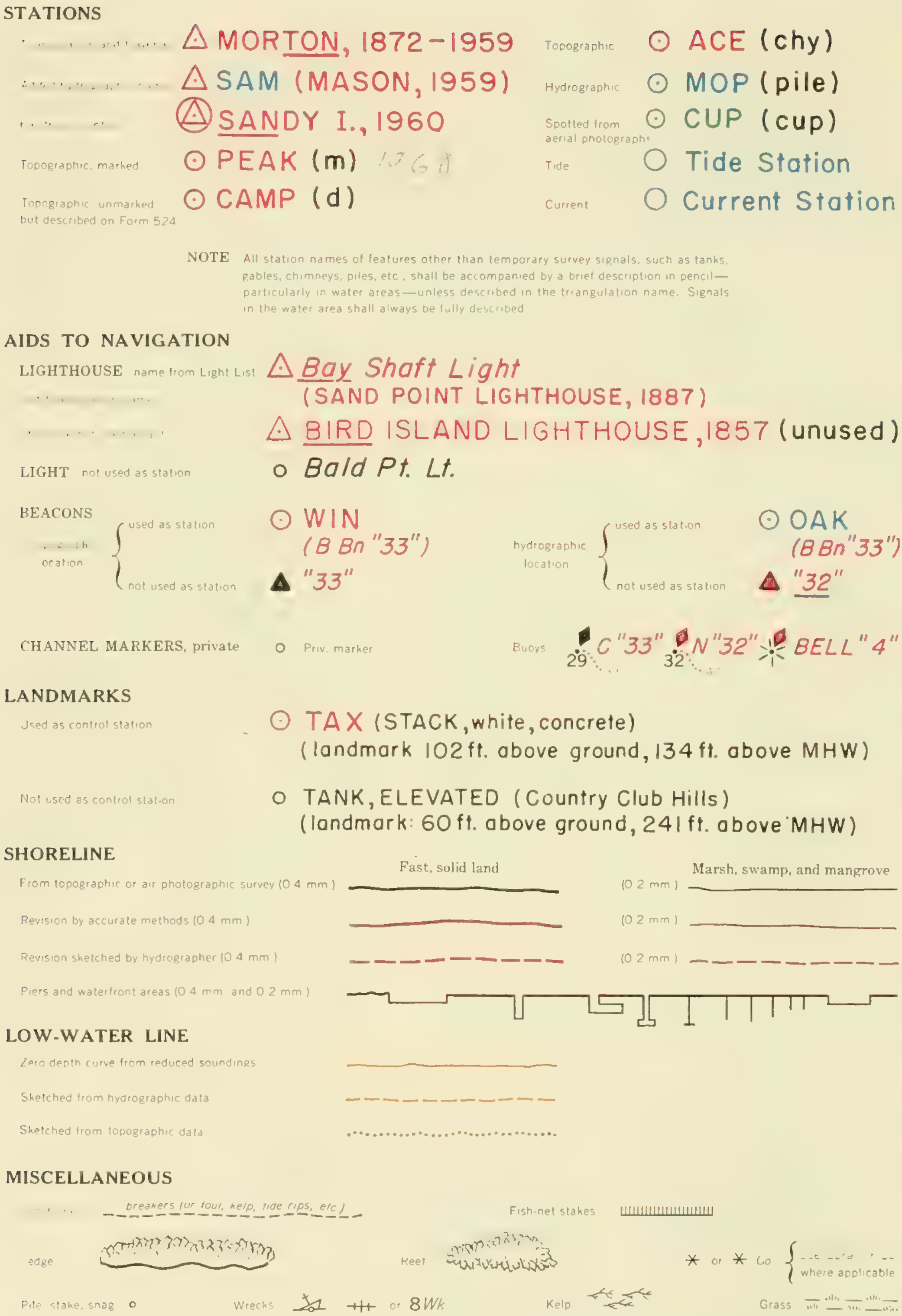


FIGURE 79. – Special symbols for use on hydrographic sheets.

in the sounding records (see 4–37). When a new name is used for a previously named station, or an entirely different name is arbitrarily used to identify a triangulation station used in hydrography, the new or arbitrary name shall be inked in blue, followed by prior name or triangulation station name in the color appropriate to the method of location and in parentheses. If part of the prior name is used, then that part shall be underlined with the station color (Fig. 79).

Names of all control stations shall be inked in capital letters 3 mm high having a line weight of not more than 0.5 mm. The Leroy lettering template No. 120C, with pen No. 00, is suitable for this purpose. The year of establishment shall be included for all triangulation and traverse stations and for all marked topographic stations or where, for other reasons, the date of establishment is noted on the photogrammetric survey.

6–25 Vertical datums.—Hydrographic survey data compiled by the Coast and Geodetic Survey are referenced to three tidal planes or datums. The sounding datum, or zero depth, for the coastal areas of the Atlantic Ocean and Gulf of Mexico is mean low water (MLW). For Pacific Ocean areas the datum is mean lower low water (MLLW). In all areas the elevations of topographic features are referred to the plane of mean high water (MHW) which is represented by the shoreline on the smooth sheet. Underlined elevations of mountain peaks are referenced to mean sea level. Local datums, such as the Columbia River Datum or a specified lake level, are used for certain of the larger navigable rivers and lakes (see 1–45).

6–26 Transfer of topographic detail.—The shoreline and all topographic details in the water area shall be carefully transferred to the smooth sheet for all inshore surveys. Topography shall generally be omitted from offshore surveys particularly where scale differences are involved. As a general rule, only contemporary photogrammetric or registered planetable surveys shall be used for transfer of shoreline. Only advance or final manuscripts shall be used when transferring shoreline and topographic detail from photogrammetric compilations (see 4–13, 14, and 15). Although the smooth sheet is not the authority for shoreline in nautical charting, the delineation of this and other details should be accurate, as copies of the survey are frequently furnished to individuals who are not aware of this fact.

The transfer may be made by burnishing reverse blueline prints of the photogrammetric manuscripts furnished at the scale of the survey. If the information is furnished in the form of a film positive, the reverse side can be coated with blue Dry-Rite ink and the transfer made by tracing the detail with a stylus or hard pencil. In each case it is necessary to make adjustments for any differences in the two projections. Transfers of shoreline from planetable sheets shall be made by tracing paper copy of the original.

If final shoreline data are not available at the time smooth plotting is started, the Washington Office shall be notified. The limits of the area and the estimated date of completing the processing shall be stated. No inshore smooth sheet shall be forwarded to the office without shoreline unless specifically authorized by the Director.

6–27 Inking shoreline.—The transfer of shoreline and topographic detail shall be carefully checked before any part of it is inked. The shoreline, specifically, the mean high-water line shall then be inked with a solid black line about 0.4 mm wide (Fig. 79). The shoreline of marsh, swamp, or mangrove areas shall be shown by a fine solid black line about 0.2 mm wide. The outlines of small details of waterfront areas, such as piers and bulkheads shall be shown by moderately fine black lines. Sections of shoreline shown on advance manuscripts by dashed or broken lines shall be left in pencil.

The shoreline shall not be generalized or smoothed. Topographic detail shall never obscure the control station point (Fig. 80). The detail can usually be omitted within the station symbol and only important features or delineations within a symbol should be shown with a fine line. Shapes of islets

shall be maintained except in areas where slight distortions are advisable to prevent misinterpretation as zero soundings.

When a section of the shoreline is revised during hydrographic operations and supersedes a prior survey for reasons of natural change or error, that section shall be inked in red (see 4–16 and 5–67). This does not apply to shoreline revisions to be incorporated in a contemporary photogrammetric survey. The revisions are usually transferred from the boat sheet or auxiliary planetable sheet which does not warrant registry as a topographic survey. The revised shoreline shall be a continuous line 0.4 mm wide if it was surveyed in accordance with topographic standards; otherwise it shall be shown by a dashed line.

The shoreline shall generally be omitted beyond the limits of the survey. Although extended or flanking shorelines are sometimes desirable for reference, excessive work on a large amount of unrelated shoreline is unwarranted.

6–28 Low-water line.—The low-water line is the curve of zero depth and is best delineated by soundings in its vicinity (see 5–17). The low-water line shall always be left in pencil on the smooth sheet until the survey has been verified in the Washington Office.

After verification the low-water line as represented by zero soundings is inked with a continuous orange line. Where it is positioned by estimated distances from a launch, it is shown by a dashed orange line. In the absence of hydrographic information, the low-water line transferred in pencil from the photogrammetric survey is inked as a black dotted line.

6–29 Limit lines.—Dashed lines on photogrammetric manuscripts used to delineate approximate limits of channels, shoals, kelp, or foul areas shall not be transferred to the smooth sheet. These lines are intended to serve as guides to the hydrographer and are usually superseded by hydrographic information (see 5–14). After the hydrography is smooth plotted, the limit lines not superseded by hydrographic information shall be

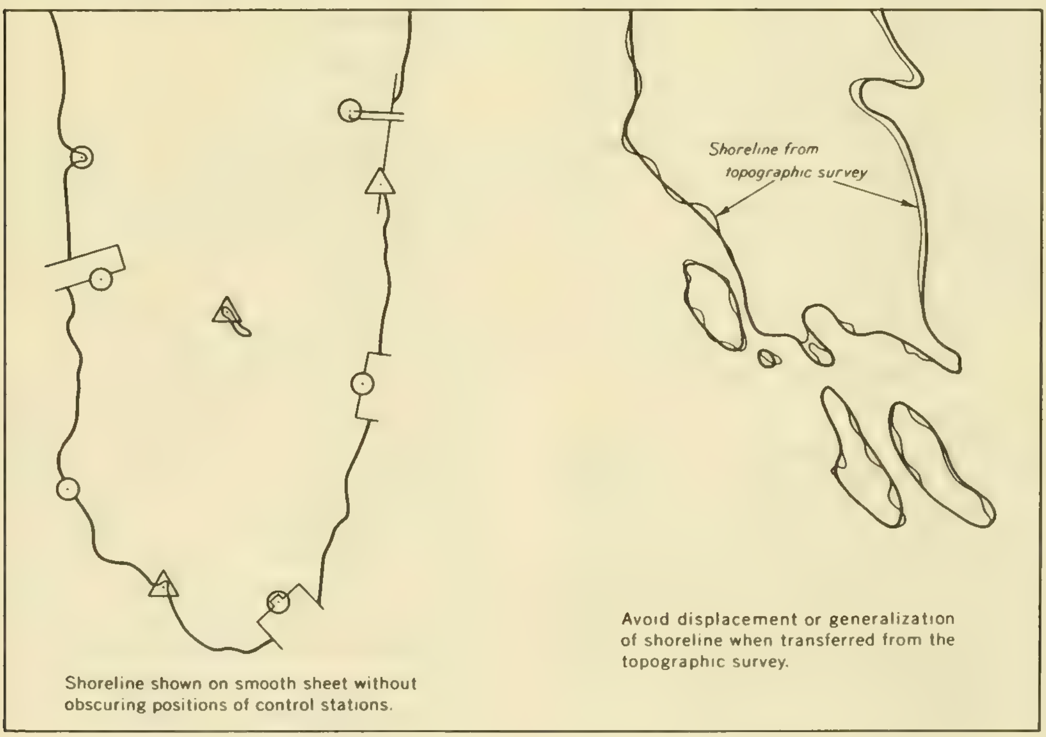


FIGURE 80.—Correct and incorrect shoreline delineations on a smooth sheet.

added in pencil. These dashed pencil lines shall be accompanied by an appropriate notation as: "shoal," "foul," "breakers," "kelp," etc., in pencil, and shall be inked in black as necessary during office verification.

Similarly, limits of other foul areas discovered during the hydrographic survey shall be defined by dashed pencil lines and identifying notes which shall be inked in black during verification. Usually these are areas which cannot be sounded because of undue risk of damage to the sounding vessel (see 5–17).

6–30 Ledges and reefs.—A ledge is a rocky formation connected with and fringing the shore and is generally above the sounding datum in elevation. A reef is a rocky or coral elevation dangerous to surface navigation which may or may not be above the sounding datum in elevation. A rocky reef is always detached from the shore, but a coral reef may or may not be connected with the shore.

Symbols for ledges and reefs (Fig. 79) transferred from the topographic survey shall not be inked until after the hydrography is plotted and any conflicting delineation is resolved. If any differences between the two surveys are not readily resolved, then inking of the symbols should be deferred until office verification. In the transfer of very small, isolated reef patches the rock-awash symbol shall be substituted for the reef symbol. On the other hand, where a cluster of closely grouped rock-awash symbols extend over an appreciable area, the reef symbol should be substituted. Ledges and reefs shall not be transferred to the smooth sheet in areas beyond the general limit of hydrography if they are within areas fully covered by adjoining surveys.

Along continuous stretches of ledge or reef, the symbol shall be substituted for zero and minus soundings of general elevation (see 6–35) when inking after office verification. Care should be taken that this symbolization is not extended through intervening beaches.

Care shall always be exercised where zero soundings occur within an area of ledge or reef symbolization that they are not erroneously inked as bare rocks or islets.

6–31 Bare rocks.—Bare rocks are those extending above the plane of mean high water. For smooth sheet work, and charting, rocks with elevations of 2 feet or more above mean high water on the Atlantic or Gulf coasts, or 3 feet or more on the Pacific Coast, shall be shown as bare rocks (Fig. 81). The actual size and shape of the rock should be shown if that is possible at the scale of the survey. Otherwise, a small single rock should be exaggerated in size and shown on the smooth sheet with an open center. Where there is a cluster of bare rocks shown by dots on the topographic survey, then one or more open-center symbols should be used. The bare rock shall never be overlapped by rock-awash or sunken-rock symbols.

6–32 Rocks awash.—Rocks awash are those exposed at any stage of the tide between mean high water and the sounding datum, or that are exactly awash at these planes. Rocks shall be represented on the smooth sheet by the rock-awash symbol (Fig. 81) where their summits are in the zone between 1 foot above mean high water and 1 foot below the sounding datum on the Atlantic Coast. On the Pacific Coast the limits are 2 feet.

The symbol shall be drawn with bold neat pen strokes. They shall not be reduced in size where there is a congestion of other rocks or soundings. No attempt should be made to plot a symbol for each rock in a closely grouped cluster of rocks. The number of symbols should be reduced to avoid overlapping symbols. When suitable, the reef symbol should be used.

6–33 Sunken rocks.—Sunken rocks are those covered at the sounding datum, that are potentially dangerous to navigation. For purposes of smooth plotting, and charting, rocks potentially dangerous to navigation, whose summits are below the lower limit of the zone for rocks awash (see 6–32), are classed as sunken rocks and are represented on the smooth sheet by symbol (Fig. 81) or by a sounding accompanied by the

legend "Rk" depending on the available information. Where several least depths are obtained on a submerged reef, then the notation should be the abbreviation "rky," indicating a rocky bottom. When the depth has not been determined and the standard symbol is used, a notation "breakers" shall be added if so noted in the records.

6–34 **Coral.**—Coral may be found as a reef fringing the shoreline, as an atoll, or as a detached coral "head" or pinnacle usually submerged. A coral reef awash or uncovering at the sounding datum shall be represented by the reef symbol with the legend "coral." Pinnacles and small patches of coral are represented by symbols for rocks with the legend "coral," or the abbreviation "Co" (Fig. 79).

6–35 **Rock elevations.**—The elevations of rocks or coral and of reefs and ledges are referenced to low-water or high-water datums as specified in 6–31 and 32. Elevations above any datum should be given in feet to the nearest whole foot. The values are always shown in slanting figures enclosed, in parentheses, close to the feature. Elevations referenced to a low-water datum shall be underlined (Fig. 81). If the elevation of a bare rock is transferred from a topographic or photogrammetric survey, the value shall be inked with red numerals about 2 mm high, and for similarly transferred rocks awash the values shall be shown in black ink. All elevations determined by the hydrographic party shall be shown in pencil on the smooth sheet and will be inked in black after office verification (see 5–67).

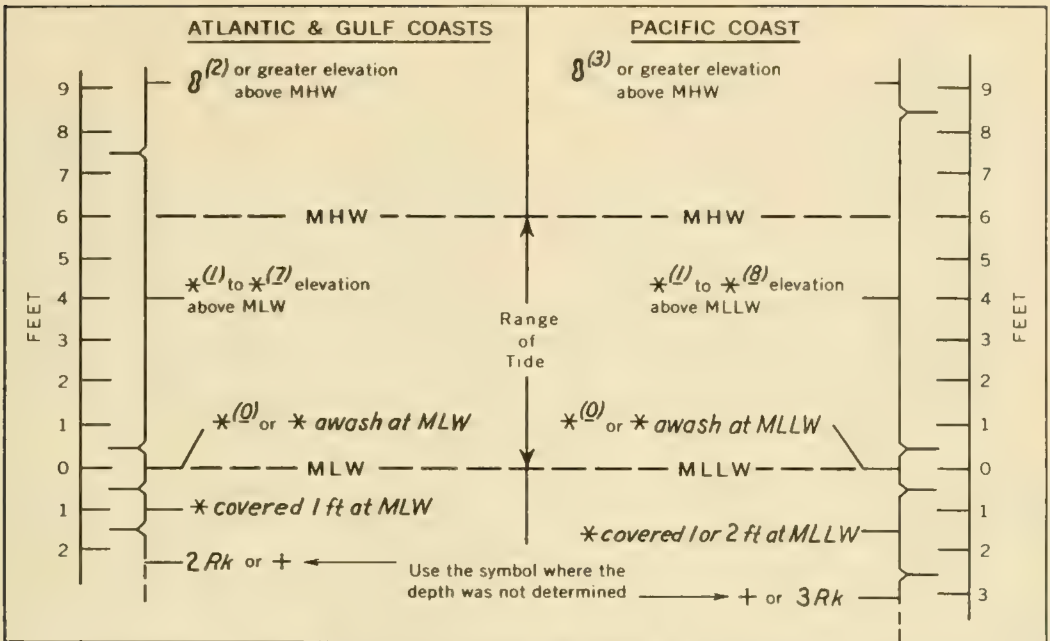
For rocks covered or exposed a half-foot at the low-water datum, the elevation is shown as zero, or the notation "awash at MLW (or MLLW)" may be substituted to emphasize the existence of a dangerous isolated rock. For rocks awash which are covered 1 foot (2 feet on Pacific Coast), the notation "covered 1 ft. MLW (2 ft. MLLW)" should be used in inland waters where the rock is seldom exposed by rough water or low tide. On an outer coast or in areas where the rock is frequently exposed at low tide, then the zero value or awash notation should be used.

Where rocks are closely grouped, the elevations should be omitted for those of lesser importance. The important values are at the outer and highest rocks. Elevations shall not be transferred from topographic surveys beyond the general limits of the hydrographic survey.

6–36 **Landmarks.**—Each landmark that is recommended for charting (see 7–18) that is within the limits of a photogrammetric or hydrographic survey must be plotted and identified on one or the other of such sheets. If the object has been used to control hydrography, it will be indicated by a station symbol appropriate to the method of location. To identify the object as a recommended landmark, the landmark name as reported on Form 567 shall be shown in black ink and in parentheses after the station name, and the word "landmark" in black ink shall be placed in parentheses below the station name, accompanied by the elevations (also in black) of the landmark above the ground and above mean high water, if these are known (Fig. 79).

The hydrographer may determine that certain structures, not recommended by the photogrammetrist, are suitable landmarks. If these have not been used as signals they should be plotted on the smooth sheet, the position of each being indicated by a black circle 2 mm in diameter, accompanied by the landmark name and other notations as above and in black ink.

6–37 **Cables and bridges.**—The locations of overhead and submerged cables shall not be transferred to the smooth sheet from photogrammetric surveys. Terminal points, such as towers or signs, used as signals shall be identified and described by suitable notes (Fig. 82). Cable and bridge clearances shall be shown on the smooth sheet only when measured in accordance with 5–82, and the data shall be left in pencil until verified in the office. When no positions for the towers or signs are available, the inshore ends of



	REFERENCE PLANE	SYMBOL COLOR Source Hydro.	SYMBOL COLOR Source Topo.	ELEVATION COLOR Source Hydro.	ELEVATION COLOR Source Topo.	ELEVATION UNDERLINED	SIZE Symbol	SIZE Elev.
8 (5)	MHW	*RED	BLACK	*BLACK	RED	NO	SHAPE	2 mm.
✳ (5)	ML(L)W	*BLACK	BLACK	*BLACK	BLACK	YES	2.2 mm.	2 mm.

*Plotted in pencil and inked during Verification

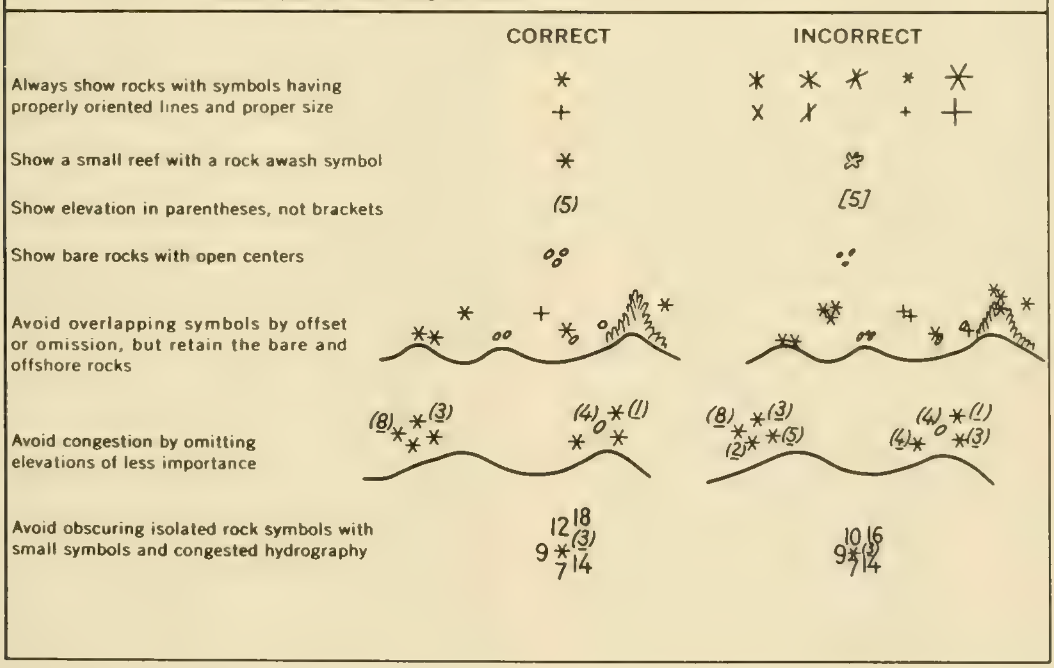


FIGURE 81.—Top—Rock symbolization and elevations referenced to tidal datums. Center—Color and size of rock symbols and elevation value. Bottom—Cartographic standards and procedures for rock detailing.

cables shall be shown by black dashed lines with appropriate notes.

6–38 Fixed aids to navigation.—All fixed aids to navigation within the area of the survey shall be shown on the smooth sheet. Most fixed aids, lights and daybeacons, are located by triangulation or on topographic surveys and are used as control stations for hydrographic surveys (see 1–50). Positions of some aids are established during the survey and may include aids rebuilt subsequent to the topographic survey. A separate report on fixed aids is required on Form 567 (see 7–22).

Where the fixed aids are used to control hydrography, symbols appropriate to the method of location shall be used, otherwise nautical chart symbols shall be used (Fig. 79), except that all fixed aids located by triangulation shall be shown by the triangulation symbol. The name or designation of each shall be shown as illustrated.

A permanent type aid which has been established by an individual or firm, whether or not it is maintained, shall be shown by the landmark symbol, if not used as a control signal, and shall be described as a "marker."

Private semi-permanent aids such as stakes, with or without baskets or kegs, along a shallow channel shall be a 1 mm circle and described as "stake."

If an abandoned light structure is still prominent and is not used as a control station it shall be shown as a landmark.

6–39 Visible obstructions.—Visible obstructions in the water area, such as wrecks, piles, breakwaters, groins, fences, duck blinds, and fish houses, are located on topographic surveys and transferred to the smooth sheet in pencil and are subject to confirmation by the hydrographic survey. They are shown by distinctive symbols (Fig. 79) or by 1 mm circles or dashed lines accompanied by a description. This information is shown in pencil by the smooth plotter and is inked after office verification.

6–40 Marine vegetation.—The limits of kelp beds or other types of marine vegetation transferred to the smooth sheet from photogrammetric surveys are subject to revision by the hydrographic survey and should not be inked on the smooth sheet. Extensive areas of marine vegetation shall be delineated by dashed pencil lines which shall be inked black after office verification, unless a line overlaps plotted hydrography. In this instance the line shall be omitted and the appropriate symbol used to the inshore end of the sounding lines where a legend can be used. Detached small areas of kelp shall be shown by symbol (Fig. 79). Grassy areas shall be shown by the note "grass" or its abbreviation "Grs."

Masses of free unattached kelp or other floating vegetation noted by the hydrographer shall not be shown on the smooth sheet. Marine growth recorded on the fathogram shall not be shown by symbol or legend unless it is reported by the hydrographer to surface or be visible at the sounding datum.

6–41 Descriptive notes.—A variety of descriptive notes is required on the survey sheet for purposes of identification, reference, and completeness of the survey data (Fig. 82). They shall be in parentheses when preceded by a name or primary designation. The notes shall be short, sometimes abbreviated, but always clear as to required information. The lettering should usually be freehand (see 6–13) and not larger than 1.8 mm for most notes, except at landmarks where the primary description shall be in capital letters 2.2 mm high. Other notes should be in lower-case letters. Differentiation for elevated or submerged features and the placement of lettering are discussed in Sections 6–14, 6–15. It is important that each control station which could be readily recovered or identified for use on future surveys, shall be described in a penciled note on the smooth sheet. When Form No. 524 is submitted for an unmarked station, the abbreviated notation for "described," "(d)," shall be placed by the station name. It is very important that stations in the water shall be described (see 5–10). To avoid any possible misinterpretation as bare rocks, dots

shall not be used over the letter i or as punctuation in the water area.

6–42 Protective overlay sheet.—After the advance work on the smooth sheet has been completed and checked, preparatory to plotting hydrographic data, the sheet shall be covered by a protective overlay. This will prevent soiling the sheet when using protractors or templates, and accumulation of dust. Thin white tracing paper, tracing cloth, or clear plastic sheets may be used for this purpose. One edge of the overlay should be folded over the top edge of the smooth sheet and secured to the back of the sheet by cellulose tape or it may be held in place by paper clips if they do not interfere with movement of the protractor. Thumb tacks shall never be put through the smooth sheet. Several tick marks at intersection of projection lines should be drawn on the overlay sheet for purposes of registration.

When positions are to be plotted by three-armed protractors, a small round hole slightly larger than the station symbol shall be cut in the overlay sheet and over each station exposing the center points for greater accuracy in plotting. This can be done with a sharp pointed bow spring divider or a punch of appropriate size. A protective backing of wood or heavy plastic should be used to prevent damage to the smooth sheet or plotting table.

Circle sheets should be covered by a sheet of very thin plastic and positions pricked with a sharp point. These positions may be plotted directly on the smooth sheet if the protractor and other tools are kept clean and unused parts of the sheet covered.

When plotting the soundings sections of tracing paper should be used to protect the smooth sheet exposing part of the sheet where soundings are being plotted. Excessive sliding of the paper over penciled soundings may cause graphite smears, especially when relatively soft pencils are used.

A waterproof cover should be placed over the plotting table during off-duty hours and it is advisable to place a caution sign on tables where smooth sheets are left.

6–43 Use of boat sheet.—If the smooth sheet is to be plotted by an individual other than the one who was in immediate charge of the survey, the hydrographer's report and the boat sheet should be examined for any information which may affect the plotting before proceeding with the smooth plot. The position or classification of control stations may have been affected by supplemental observations. The sounding volume index should be examined for information pertinent to the control in order to avoid later replotting because of a revised position of a hydrographic station. Also, the transfer of certain explanatory notes from the boat sheet to a corresponding position on the overlay may clarify subsequent confusion during smooth plotting due to twin objects or other control problems, names, or other vagaries of survey work on the water.

The boat sheet is invaluable as a guide for smooth-plotting the sounding-line courses, individual positions, and features (see 5–4). The hydrographer sees and plots conditions which may inadvertently be recorded in error or may not be recorded at all. He might see an object to port and plot the line accordingly, yet unthinkingly call starboard to the recorder or not report at all. He might survey an inshore line by running parallel to the beach or by running straight lines from point to point and show the courses properly on the boat sheet without either of the alternative courses being recorded. There are many other instances of boat sheet guidance. Each circumstance shall be evaluated from all available information.

6–44 Development overlays.—Overly congested hydrography sometimes results from necessarily persistent sounding over a reef, shoal, or obstruction and in a constricted passage or in areas adjacent to waterfront structures. All lines required to position the least depth and define bottom configuration by depth curves shall be plotted on the smooth sheet (see 5–25). Subplans are sometimes used to plot the hydrography and other detail at a large scale. Supplemental overlays plotted on tracing cloth may be used where necessary to avoid congested

hydrography on the smooth sheet. The overlays shall be page-size, complete with projection, inked soundings and position numbers, and shall be inserted in the descriptive report. A note "see overlay" shall be made on the smooth sheet. Overlays should not be used when essential hydrography can be clearly shown on the smooth sheet.

6–45 Combination boat and smooth sheet.—When the combination boat and smooth sheet method of plotting is used (see 1–10 and 5–5), there is necessarily a limiting time factor. The positions shall be plotted as accurately as circumstances permit. The position should not be pricked through to the smooth sheet unless the field plotter has a firm position. Doubtful positions should be plotted later when there is sufficient time to evaluate the position data. On electronically-controlled surveys the positions should not be pricked through unless the distance corrections are known and applied. Final calibration of distance measuring equipment should not result in a significant shift of positions. The error in a hydrographic position plotted by this method should not exceed 1 to 2 mm depending on whether the sounding is a 1- or 4-digit number and the general character of the bottom. Greater tolerance can be permitted in areas of smooth bottom or in great depths than in areas of irregular bottom. Critical detail, such as the least depth on a submerged danger, shall be replotted to its correct position when final calibrations differ by a plottable amount.

Soundings and other hydrographic detail plotted under this field procedure shall conform to the standards of accuracy and cartography set forth elsewhere in this chapter. It is advisable to defer plotting of soundings on the smooth sheet until the survey is otherwise complete.

6–46 Position plotting.—Hydrographic positions are usually plotted in the order in which they were observed and recorded. This systematic procedure will help to prevent accidental omission of recorded data which should be plotted. If the plotting is done while field work is still in progress, it may be preferable to plot the positions in critical areas first in order to give immediate evidence whether additional field work is required in the area.

The plotter should be particularly careful to watch for uneven distortion of the smooth sheet when using a 3-armed protractor to plot cuts to signals or other details at some distance away. In plotting Shoran distances directly from floating stations, compensation for distortion in the smooth sheet should be made. This can usually be done by marking circle intervals in a strip of plastic to correspond with circles drawn on the sheet from a fixed station.

6–47 Minimized protracting.—Two smooth plotting procedures are authorized which are designed to reduce the number of fixed positions plotted by protractors. These procedures and the limitations imposed on each are described in the following paragraphs. Both procedures are applicable only for surveys of areas having a uniform depth or gently and evenly sloping bottom.

When the hydrography is controlled by sextant fixes based on final positions of control stations and the hydrography has been accurately and legibly plotted on the boat sheet, a film positive copy of the boat sheet may be used to transfer positions to the smooth sheet (see 5–63). The first and last positions and infrequent intermediate positions on a line shall be lightly pricked through the film positive to the smooth sheet and shall be checked by protracting. If the transferred positions differ significantly from the protracted positions (see 6–45), the transfer method shall be abandoned for the line or area or for the entire sheet when several tests reveal similar differences. If the check proves consistent accuracy of the boat sheet plotting, the remaining positions can be transferred without check (see 5–50). Adjustments must be made for any differences in the two projections. Transfers may also be accomplished by use of paper tracings.

Detached positions, positions of limited-area development lines, and positions con-

trolling critical hydrographic data shall never be transferred in this manner.

Where the transfer method is considered a proper one, the chief of party shall request the film positive from the Washington Office when the boat sheet is forwarded for preliminary application of new information to the chart. The proposed transfer will be evaluated and the film copy furnished if the proposal is approved.

The second procedure for minimizing protracting of positions is to omit protracting some positions as specified below:

Where the sounding lines or segments of lines are apparently straight for three or more positions, or if the lines follow distance arcs closely, the protracting of not more than two consecutive positions on the line may be omitted. The first three and the last three positions on each line shall be protracted. Positions at abrupt changes in course shall be protracted. The positions of all critical detail and all detached positions shall be protracted.

Positions not protracted shall be located along the line in proportion to time intervals and shall be numbered in the usual manner. Positions so located shall be checked in the record book with a small letter "n" in lieu of the usual check mark.

Positions determined by electronic distance measuring devices can be plotted so rapidly by Odessey protractors that little time is saved by these methods.

6–48 Use of protractors.—Three types of protractors described in Sections 3–16 to 22 are used in plotting hydrographic positions. Three-point fixes are plotted by use of three-arm metal or plastic protractors. Metal protractors should be tested and adjusted, if necessary, before plotting is started and periodically while in use (see 3–18). Plastic protractors cannot be adjusted, but should be tested daily while in use. Index errors can be determined and applied to observed angles when plotting positions. Plastic protractors may warp, particularly near the ends of the arms, and the usable part of each arm should be determined and marked or the fiducial lines on the warped portion should be rescribed. Plastic protractors having an index error greater than 3 minutes in either arm from causes other than warping of the fiducial lines should not be used for smooth plotting (see 3–21). There is no objection to the use of plastic protractors for plotting at full range of the arms, provided that the positions are correctly plotted.

Metal protractors are more precisely constructed than the plastic models and shall be used to plot all detached positions for location of signals, rocks, buoys, least depths on shoals or obstructions, and to plot weak fixes.

Three-armed protractors shall be moved into position by grasping the circle and the fixed arm; the movable arms shall never be used for this purpose. Plotters must be especially careful when using a metal protractor with extension arms attached.

For plotting a position close to a control station, it is occasionally necessary to use a small unarmed protractor made by marking the angles on a printed transparent compass circle.

When electronic ranging systems are used to control the hydrography, Odessey (see 3–22) protractors are used to plot the positions. The concentric circles on this type of protractor permit centering it at a point representing an increment from the nearest distance circle drawn on the sheet.

6–49 Abnormal Positions.—Abnormal positions are usually the result of error, misunderstanding, expediency, or necessity incurred by the nature of hydrographic surveying.

When only one angle is recorded or accepted the position is plotted on the locus of the single angle at a point adjusted for time and course from adjacent positions. Acceptance of this position depends on steady speed and course of the survey ship and also on a strong line of position for the locus of the single angle. If the position is indefinite, the soundings should be plotted according to time, angle, or other hydrography. If several consecutive positions are not firm it may be necessary to reject that portion of the line. This action shall be recorded in the sounding

volume, and in the descriptive report or addendum if the rejection impairs the survey coverage.

When four stations are mistakenly observed and there is not a common center station for 3-arm protracting, the position is fixed by the intersection of two arcs formed by plotting loci of the two angles.

When the position is weak or indeterminate because loci of the two angles approach tangency or actually coincide, acceptance of the position should depend on criteria stated for a single angle position. The plotter should be on guard against the "swinger"; and if this condition is suspected then the position should be protracted a second and third time after moving the protractor completely away from the initial position. A swinger will result in the plotting of several points on an arc.

Weak positions occur sometimes on electronically controlled surveys where the control is inadvertently used beyond the limits of strong intersections. Conflicting hydrography may occur at the extended along-shore or inshore limit of the survey where it makes junction with visually controlled hydrography. Where both systems are used on the same smooth sheet, the visual work in the junctional area shall be plotted first and shall usually be retained where conflict arises from the weaker electronic control.

Estimated positions are sometimes recorded when it is not possible, feasible, or necessary to obtain a 3-point fix. They occur close inshore where a normal fix may not be possible, and the distance from the beach, a structure, or station is estimated. Ends and sometimes beginnings of lines are plotted by time interval on the extended line, provided there was no change in speed since the last two positions or before the first two, respectively. Structures and objects such as beacons, buoys, rocks, piers, etc., are noted in the sounding volume at the moment of passing by the survey launch. These notes afford a check on the survey work, positively record which side of the object was sounded, and also document the existence of features at a specific time. These objects are estimated as to observed distance and are recorded at observed time between recorded positions. Skillful evaluation of both elements is required in resolving occasional discrepancies resulting from these estimates. Sometimes when locating a rock or reef it is necessary for the launch to stand off because of rough water, and an estimated distance is recorded. In event of differences with other positions of the same features, considerations should include the possibility of incorrect estimates or unrecorded "stand-offs."

Estimated positions are necessary to fix the positions of soundings after a survey ship makes a sharp turn and continues to sound. The forward momentum of the ship varies with size, hull and speed, and it should be usually recorded by the boat sheet plotting and information recorded by the hydrographer.

There are places in hydrographic surveys where it is impossible to obtain a three-point fix or other position data especially in narrow winding sloughs. The hydrographer, in such cases, spots his position on the boat sheet from the adjacent features of the shore line and the note "see boat sheet" is entered in the sounding record. The smooth plotter should transfer such positions, and lines between positions, to the smooth sheet.

6–50 Erroneous positions.—Two important qualifications of a competent smooth plotter are his ability to recognize an erroneous position immediately and the soundness of his judgment in deciding the most probable correction which must be made. When parallel straight lines are run with a uniform interval between positions, an error in position data is immediately apparent when the distance between positions changes without a change of speed otherwise indicated, or when the position plots off the line without a change of course shown in the record. Other errors in positioning may not be disclosed until discrepancies in depths are found when soundings are plotted. Detached positions not substantiated by check angles should be carefully evaluated when they are plotted.

Errors usually occur because of the nature

of hydrographic surveying—foggy or hazy visibility, the distortion of conversation caused by wind, sea, and motor noise and occasional confusion resulting from rapid mobile operations.

In many cases an erroneous position can be salvaged by recognizing the nature of the error and correcting the recorded data. The data shall never be erased or obliterated; revision shall be entered in colored pencil and the erroneous data crossed out. The boat sheet may show the position correctly. Errors which are most likely to occur in recorded position data are as follows:

(a) The station name may be incorrect because (1) a change in the observed station was not reported to the recorder, (2) the recorder misunderstood the name for a similar name, or (3) the wrong object was observed because of misidentification of the station, in which case one angle was rejected.

(b) The angles or the degrees and minutes may be reversed in the record.

(c) The sextant might have been read erroneously. Common-type of errors are the misreading of an adjacent division, either 20′ or 30′ where either of these values is the smallest arc division; or 10′ on the drum of the Navy-type sextant; 1° on either sextant; 2°, 4°, or 6° when a 1°, 2°, or 3°-increment is erroneously applied on the wrong side of the longer 5° or 10°-division; 5° and 10° for the same reason as for 10′, 20′, 30′ and 1°. Although past experience at time of sextant observation and in subsequent plotting attest to repetition of these errors, they shall not be corrected during plotting unless the substituted value is absolutely confirmed by other factors, such as time and course, boat-sheet plotting, reference hydrography or objects, etc.

(d) The recorder may have misunderstood the value of the angle and recorded 15 for 50, 7 for 11, 5 for 9, and vice versa.

(e) A station position is in error, such as a weakly located hydrographic or supplemental station, in which case hydrographic discrepancies are traceable to its repeated use. Sometimes more careful evaluation of original observations and search for later observations in the records will result in a corrected position.

(f) Electronically controlled positions, may be in error because of deficiencies in correction values, including corrections for inclined distances where the ship is close in to a highly elevated shore station. The latter may occur off coasts where the inshore limit of ship hydrography makes junction with visually controlled launch hydrography.

6–51 Position identification.—Each plotted position should be carefully pricked through the overlay sheet to the smooth sheet. The needle point should not be pushed through the smooth sheet, but should make a small identifiable indentation in the surface of the paper. After a line or several lines of positions have been plotted, the cover sheet shall be rolled back and the positions on the smooth sheet identified by number and day letter. Each position point shall be accentuated by a fine dot of ink of the same color as the day letter and number and shall correspond to the color used in the sounding record. Pencil lines shall be drawn lightly between positions as guides for plotting soundings.

Position numbers are usually added in pencil at intervals sufficiently frequent to permit positive identification of all positions when the protracting has been completed. It is especially important to defer inking position numbers in areas of closely spaced hydrography, but it is equally important that the positions shall not be misidentified when the numbers are inked.

Position numbers are inked in color and case as shown in the sounding record (see 5–34 and 35), with vertical letters and numerals about 1 mm high (Fig. 82). Each position shall be numbered and the day letter shall be shown at the first and last position on a line, at each significant bend in the line, at each position whose number is a multiple of 5, and at each detached position. If possible the number should be placed below and to the right of the position dot with enough space between them to permit inking the sounding without crowding or obscuring the position number. If a number

must be displaced some distance it may be connected to the position by a dotted line in the same color. A solid line leader shall not be used. It is essential that position numbers cannot be misread as soundings on photographic copy, yet will not be so small as to require the use of a magnifying glass to read them.

6–52 Record of plotting.—The smooth plotter shall maintain a record of his actions in the sounding volume, using a pencil of identical color for all entries and corrections. A checkmark, in the same color, shall be placed beside the recorded data for each position plotted and accepted. Each recorded change of course and each note in the remarks column should be checkmarked as the information is applied to the smooth sheet. All revisions, amendments, or new information shall be entered in the same color and initialed. The original recorded data shall never be erased. Corrections and revisions shall be made by neatly crossing out the recorded data and entering the correct data above the erroneous data. An erroneous entry which cannot be logically revised on the basis of available information shall be rejected and this action indicated by a capital "R" adjacent to the entry. Authority or reason for revision or rejection shall be stated in the volume unless it is clearly obvious.

When least depths or other critical information are not plotted and not rejected for the reason that they are superseded by data recorded elsewhere in the sounding volumes, a note shall be entered adjacent to the data not plotted stating where the superseding data are recorded, as "see pos. 22d—Vol. 3—page 48."

Only those positions which are actually plotted shall be checkmarked. When estimated positions or protracted positions are transferred from the boat sheet to the smooth sheet, this fact shall be noted in the sounding volume.

Stamp No. 38 (Fig. 70) is impressed at the end of each day's work and the smooth plotter shall enter his initials in the appropriate place to indicate that the positions have been smooth plotted.

6–53 Soundings.—The soundings and related hydrographic detail required for the compilation of nautical charts are the principal products of hydrographic surveying.

Before proceeding with the plotting of soundings the smooth-plotter shall check the record of processing accomplished on the sounding records. Completion of each phase of processing from check-scanning the fathograms through checking the reduced soundings should be indicated by the initials of the persons responsible therefore in the appropriate spaces of Stamp No. 38. If the initials have not been entered, the smooth plotter should assure himself that the work has been done, or perform the necessary work and have it checked before penciling soundings on the sheet.

The plotting of soundings on the smooth sheet usually follows the same procedure as plotting positions; that is, the plotter begins with the first position in Volume 1 and plots the soundings in the order in which they were recorded. This is not mandatory, and it is sometimes preferable to plot soundings on crosslines first or to complete the plotting of an intensively developed area without regard to chronological order. Soundings on crosslines shall be retained in preference to soundings on the regular system of lines except where the latter are shoaler. When the chronological order is not used there is danger that some essential information may be overlooked, particularly when the plotter is unable to complete the sheet because of transfers of personnel or other reasons.

The soundings should be accurately and neatly penciled on the smooth sheet in accordance with instructions contained in the following sections. Although the soundings are subject to verification or revision in the office, they may be used for charting prior to verification. If the field work and smooth plotting are accurate and complete only minor revisions of the chart may be necessary after final review of the sheet. On the other hand, inaccurate or incomplete work may result in charting false information, thus creating a hazardous situation.

6–54 Identification of least depths.—

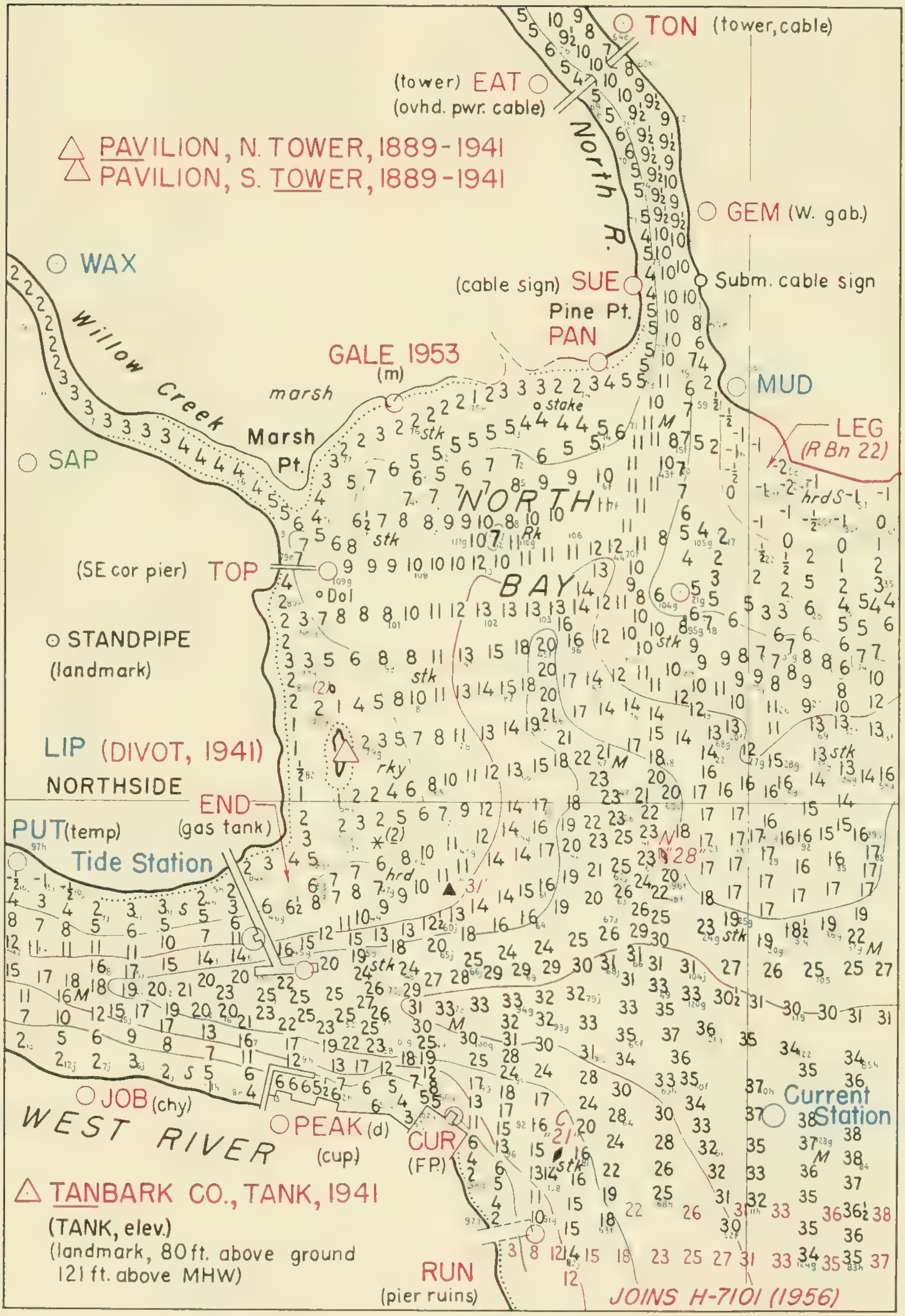


FIGURE 82. - Section of completed smooth sheet reproduced at actual scale showing specified plotting of hydrographic and topographic detail.

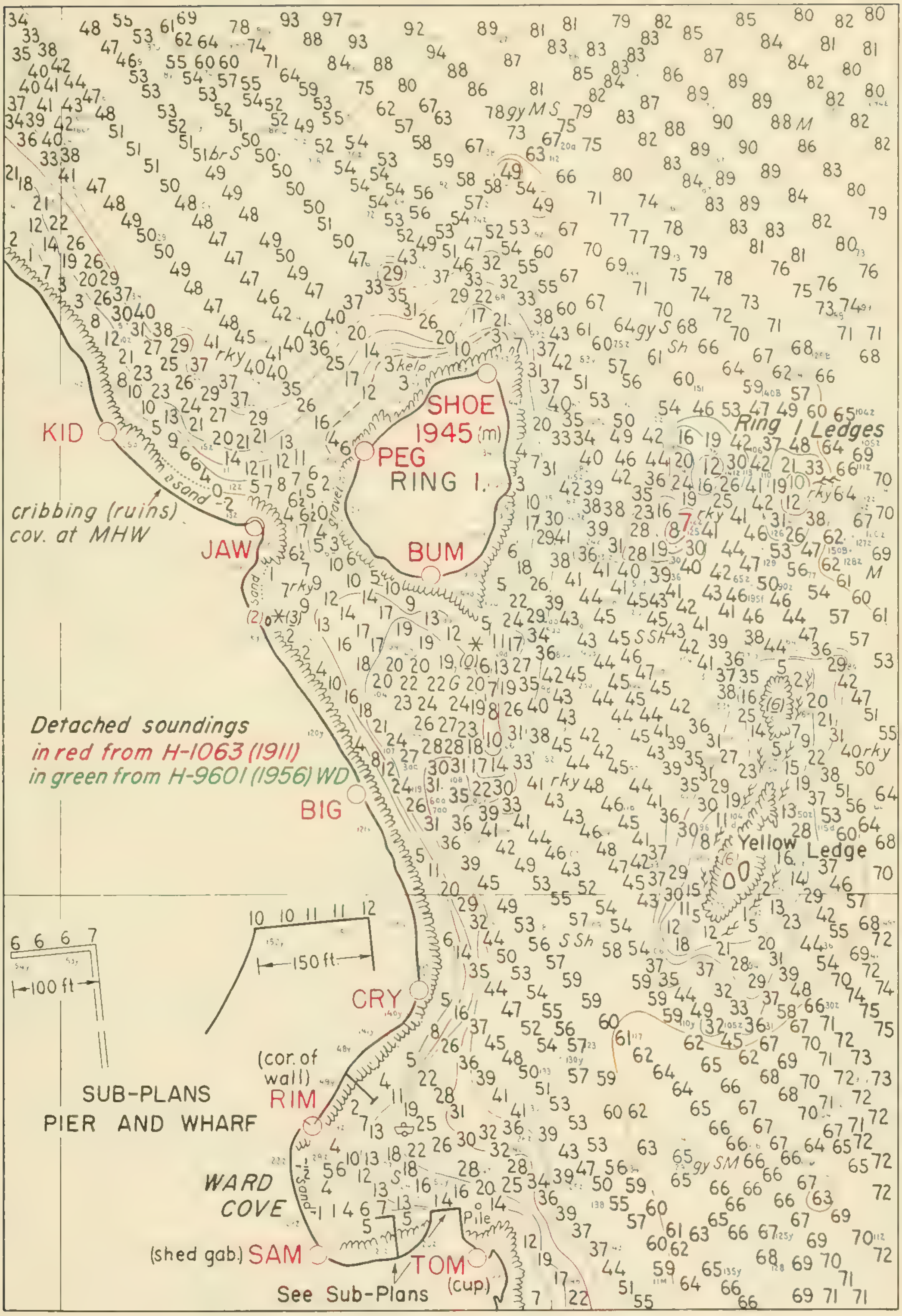


FIGURE 83. – Section of completed smooth sheet reproduced at actual scale showing treatment of congested hydrography and miscellaneous details.

Least depths on submerged dangers to navigation and in channels are critical data which should be readily identifiable on the smooth sheet. To facilitate identification of such features and to emphasize a critical depth in an area of congested hydrography it may be advisable to place a temporary pencil note on the sheet. The note should state the least depth and position number and should be placed in an otherwise blank area nearby. A short pencil arrow may be drawn towards the feature but should not be drawn across soundings.

6–55 Sounding units.—The sounding units to be used in various areas and depths are specified in 1–38, and corresponding correction units are specified in 5–101. Only one unit, fathoms or feet, shall be used on a smooth sheet.

On a smooth sheet whose depth unit is feet, the soundings shall be plotted in integral feet, except in the following places where they shall be plotted to the nearest half-foot:

(a) At important points on navigable bars.

(b) At controlling depths in dredged or natural channels.

(c) On both sides of the low-water line.

(d) Where necessary or desirable for better definition of the depth curves (Fig. 85).

When plotting fractional units in feet, the reduced decimal values 0.3 to 0.7 foot shall be plotted as ½ foot. This rule also applies to minus soundings.

When plotting soundings in integral feet decimals less than 0.8 foot are disregarded and decimals of 0.8 and 0.9 are increased to the next whole unit, except for minus soundings where decimals less than —0.3 foot are disregarded and decimals —0.3 to —0.9 are treated as —1.0 foot.

On a smooth sheet whose depth unit is fathoms, soundings shall be plotted as follows:

Minus soundings and soundings in depths less than 11 fathoms in fathoms and tenths. In depths greater than 11 fathoms the soundings shall be plotted in whole units, except within areas of smooth bottom and gentle slope where soundings are charted in feet, soundings shall be plotted in fathoms and tenths to 31 fathoms and between 31 and 101 fathoms to the nearest half-fathom. These same units shall also be used when plotting soundings in the overlap area on surveys plotted in fathoms which join soundings plotted in feet. In all areas fathoms and decimals should be plotted where necessary for more accurate definition of depth curves.

When plotting soundings to the nearest half-fathom, decimals of 0.3 to 0.7 shall be plotted as ½ fathom. When plotting soundings in integral fathoms decimals less than 0.8 shall be disregarded and 0.8 and 0.9 fathom are increased to the next whole number.

If it is necessary to convert reduced soundings from fathoms to feet, or vice versa, the conversion shall be made according to Table 12 and 5–123.

In plotting fractional units for better definition of depth curves, it is not necessary to plot all fractions at the contour depth. A lightly penciled dot beside the integer can be used as the plotting progresses and the fractional parts penciled later on the deep side of the curve.

6–56 Size of numerals.—numerals representing soundings shall be 2.2 to 2.5 mm in height. At this size legible photographic copy can be produced even at a reduced scale. A ruling pen opened to the required size provides a satisfactory gage for penciling soundings of uniform height. Soundings which mark least depths in areas of congested hydrography should be slightly larger and bolder than the above unless accentuated by a depth curve. Such soundings are among the most important in the area and should be apparent on cursory examination of the sheet.

6–57 Fractions and decimals.—Figures in a fraction or the decimal parts of a depth unit shall not be larger than half the size of the integer. The over-all height of a fraction should not be more than 15 percent greater than the height of the integer.

Where a fraction stands alone the horizontal bar between the numerator and denominator must be included to avoid mistaking the component parts as whole numbers. The bar shall be omitted when the sounding is a mixed number.

The decimal part of a fathom shall be plotted as the numerator of a fraction whose denominator is 10, but with the denominator omitted. The horizontal bar of the fraction shall be retained. Where depths are less than one fathom, the decimal part shall always be preceded by a zero, as $0^{\underline{4}}$. Great care is necessary when penciling and inking soundings that numbers in a fraction or decimal cannot be mistaken as whole numbers and that they are not separated from the integers in mixed numbers.

6–58 Soundings at positions.—The center of the number, including the fraction if any, is considered the position of that sounding except for soundings at positions. In penciling and inking soundings at positions it is important not to obscure the position dot, or position number, by any part of the sounding. A single digit sounding should be slightly displaced if necessary to avoid obliterating the position dot, however a single digit representing the least depth on a sunken rock or pinnacle should be centered on the position. For 3-digit soundings the first digit shall be placed to the left of the dot and the others to the right of it.

Digits adjacent to position dots shall never be positioned so that the dot might close any part of the digit thus changing its value on photographic copy. If a 6 or 9 are so drawn that the dot is below or above the tail, respectively, the figures might be misread as 8. The same precaution should be taken when drawing the figure 3.

6–59 Spacing of soundings.—Soundings are recorded at regular intervals appropriate to the scale of the survey, speed of the sounding vessel, and depth of the water (see 5–29). Additional soundings are scaled from fathograms as necessary to reveal the bottom configuration.

The spacing or density of soundings on the smooth sheet shall be such that all depth curves are adequately delineated and the configuration of the bottom fully revealed. These objectives are partially accomplished by the spacing of sounding lines. The spacing of soundings between positions shall be generally uniform on the smooth sheet, except as noted in 6–60. This requirement should be considered when there are noticeable differences in distances between consecutive positions, as when parallel lines are run with and against strong currents.

For generally smooth bottom the spacing of soundings on east-west lines should not exceed 5 mm for single-digit numbers, 7 mm for 2 digits, 10 mm for 3 digits, and 15 mm for 4-digit numbers. On north-south lines the spacing should be 5 mm for single-digit numbers to 7 mm for 4 digits. The spacing for mixed numbers, integers with fractions or decimals, should be slightly less on east-west lines. These are general criteria useful where a selection of soundings is possible (see 5–29).

Where the bottom is irregular the spacing of soundings will also be irregular because of the requirement to plot soundings at abrupt changes in the slope of the bottom and the peak and deep soundings which characterize the bottom as bumpy, undulating, ridged, or channeled. Soundings which mark least depths on dangers to navigation and deep soundings which reveal channels for navigation are most important. In plotting multiple-digit soundings in some areas it may be necessary or advisable to decrease the routine spacing between soundings and to orient 3- and 4-digit soundings at an angle (Fig. 84, also see 6–14).

The primary consideration when plotting soundings is that each sounding shall be plotted in its correct geographic position as established by the sounding interval or fraction of an interval and the speed and course of the sounding vessel. Accurate spacing of soundings between fixed positions is attained with the use of a spacing divider. When using this guide, a continual surveillance of the sounding record is required to note changes of speed or course and changes in

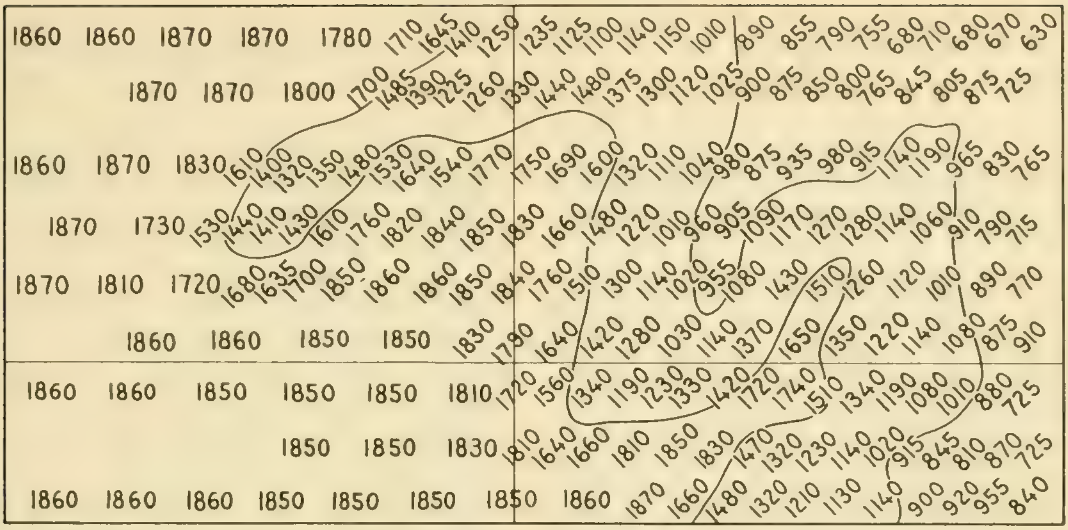


FIGURE 84.—The plotting of 3- and 4-digit soundings at an angle is necessary to permit close spacing of soundings required to portray irregular bottom configuration.

the sounding interval and to avoid erroneous spacing and positioning of soundings.

6–60 Selection of soundings.—It is usually necessary to select soundings in the record for plotting on the smooth sheet. It cannot be emphasized too much that proper selection of soundings is essential for complete and accurate portrayal of bottom configuration. The fathogram should be in view when plotting soundings in order that the plotter will have a proper conception of the profile to be reflected by the soundings. If it is evident that the recorded soundings reflect a mechanical or careless scanning of the fathograms, it will be necessary to rescan them. It is recognized that not all irregularities can be represented at the scale of the smooth sheet, and that minor relief in very irregular bottom must be generally disregarded. But it is essential that significant peaks and deeps shall be scanned and plotted. When selecting soundings which are inserted at uneven intervals this action shall not result in small distorted numerals or numerals which run together and fail to identify individual soundings. Under such conditions the slope sounding should be omitted unless it is advisable to select another sounding from the fathogram.

Inasmuch as the survey sheet should reflect the relative density of hydrography, the shoal and channel developments, investigations, and crossline soundings should be evident on initial inspection of the completed sheet. In the event congested development is partially plotted on an overlay (see 6–44), a note on the sheet should highlight the supplemental plotting. However, the least depth and other depths needed for delineation of depth curves and bottom configuration plotted on the overlay, shall be transferred to the smooth sheet.

Where routine plotting of soundings involves overlaps or crossings of hydrography, the shoaler soundings shall be plotted but consideration shall be given to selection of soundings and retention of the identity of the sounding line. There should be no hesitation about erasing previously plotted soundings, but the deletion should not impair the paper surface or legibility of adjacent soundings.

6–61 Discrepancies in hydrography.—During the plotting of the soundings and the delineation of the depth curves, the smooth-sheet plotter must be ever alert to detect errors in the hydrographic data. Discrepancies related to control and hydrographic positioning are discussed in 6–50, but there is a great variety of errors which

may occur. If errors are discovered or suspected, they must be verified and corrected whenever necessary. No deviation from original recorded data shall be made unless this seems reasonable and is supported by other evidence. Some of the more common causes of discrepancies found in smooth plotting are:

(a) Fathograms may be improperly or inadequately scanned. This may be the result of even-interval scanning and omission of peaks and deeps; or improper interpretation of echoes from marine growth, strays, and side echoes.

(b) An unnatural depth may result from a 5- or 10-fathom error in scanning or from an error in reduction of the sounding. On overlaps and crosslines it may result from even-interval recording of a sounding which should have been recorded at a fraction of an interval, or from incorrect spacing of soundings across the side of a channel or other steep slope. An anomalous depth may result from an unrecorded departure from a straight course between positions near the edge of a channel or bank, but the offset sounding should be disproved by overlapping hydrography before it is rejected. Detached leadline or wire soundings obtained incidental to sampling the bottom may be erroneous for various reasons.

(c) There are many reasons why a line of soundings might disagree with other hydrography. If the differences in depths vary inconsistently, particularly if the course appears erratic, the discrepancy usually originates with the control. If the differences are generally consistent then they may be due to one factor or a combination of several, as unrecorded wind tides; echo penetration or shoaler reflection of soft bottom caused by variations in gain or by uncorrected variations in two echo sounders; echo sounding versus leadline or pole sounding in soft bottom; changes in the initial on the fathogram; errors in phase correction; deficiencies in the calibration of echo sounders; omissions of or deficiencies in settlement and squat corrections of the survey ship or launch; or erroneous scanning of saw-tooth profiles.

(d) Where considerable hydrography is in disagreement, the discrepancies may be caused by one or more of the following: inaccuracy in sounding line control which may be caused by inadequate calibration of electronic control or incorrect application of calibration corrections; errors in the positions of signals or weak fixes; inaccuracies in the soundings obtained by one or both sounding vessels in the junction area or by more than one vessel working on the same survey; inadequate tidal information or incorrect zoning between tide stations.

Since data may be transferred to the chart from the smooth sheet before it has been verified and reviewed, all discrepancies shall be resolved insofar as practicable before the sheet and records are forwarded to the office. In areas of flat or gently sloping bottom and depths less than 11 fathoms, discrepancies of one unit in feet or 0.2 unit in fathoms can be expected occasionally, and, except where these differences affect a natural delineation of depth curves, they do not justify extensive investigation. The report on smooth plotting shall include references to all significant unresolved discrepancies.

6–62 Bottom characteristics.—All recorded bottom characteristics shall be penciled on the smooth sheet except when an excessive number of them are recorded on pole or leadline surveys. In the latter case a selection should be made being careful to plot all isolated rocky or hard bottom characteristics. On an ideal survey of important waters, such as harbors and anchorages, the plotted characteristics should be adequate to define the approximate limits of various types of bottom in the area. On some echo-sounding surveys where bottom characteristics have not been determined with sufficient frequency (see 1–42), and where prior surveys have been made, characteristics will be transferred in color from the prior survey during office review in areas where no changes in depth have occurred.

Standard abbreviations for bottom characteristics have been adopted (see 5–88) and shall be used on the smooth sheet. The first letter of the nouns shall be capitalized

and periods must not be used. The abbreviations shall be lettered in single stroke slanting letters with the capital letters not more than 2 mm in height.

Bottom characteristics should be placed on the smooth sheet reasonably close to and a little below and to the right of the soundings which they accompany, provided there is adequate space. Otherwise the characteristic can be placed in any convenient place nearby. However, in displacing the characteristic it shall never be placed where it does not represent the nature of the bottom unless displacement is indicated by a penciled arrow. The descriptive note "Rk" should always adjoin least depths on submerged rocks when so identified in the sounding records.

6–63 Standard depth curves.—After all the soundings are plotted standard depth curves listed in Table 3 shall be lightly penciled on the smooth sheet. The curves will be inked in the specified colors after office verification (Fig. 82, 83). Depth curves, or curves of equal depth, are comparable to contours on land and the principles governing the delineation of contours are equally applicable to the drawing of depth curves.

The curves shall be drawn with a 3H pencil having a slightly rounded point, never a sharp one, and care shall be taken not to indent the paper. Inked lines shall be less than 0.4 mm wide, and in congested areas should be consistently about half this width.

Depth curves shall generally be drawn to include soundings of equal depth or less, but they may be broken at soundings in order to avoid unnatural bottom configuration. Curves shall never be broken vertically above and below the numeral 1 or on a 45° alignment with the left part of the numeral 4. They should never overlap or cross a letter, numeral, or symbol. Curves should be broken into long dashes where they are not adequately defined. In some inshore areas only short sections or indications of curves can be drawn. Where they can be extended with reasonable certainty of position, inshore depth curves should be completed to the extent determined by the hydrography. In comparatively shoal depths where there may be dangers to navigation, one should always err on the side of safety in drawing depth curves.

The curves shall not be drawn mechanically; they should delineate a natural bottom configuration, but from a cartographic viewpoint the minor irregularities in soundings should not be over-emphasized in drawing the curves. There are two reasons for this policy; first, with soundings plotted in integers a tenth of a unit change, 0.7 to 0.8, results in a full unit change in the plotted sounding; and second, continuous minor undulations and irregularities along a depth curve lessen desired emphasis on the more significant irregularities. These criteria are difficult to detail in a description and are best cited by illustration (Fig. 85). Generalization is desired to a point, but significant configurations of the bottom shall not be masked by unjudicious smoothing of curves.

The use of ½-foot fractions for judicious modification of curves is specified in 6–55d. This ½-foot leeway also applies to 0.1 fathom. Either should be omitted to eliminate unnatural curve delineations and to smooth insignificant irregularities. Both should be omitted for emphasis of the apex of a shoal or end of a spur or elongated shoal. The fraction should be plotted where it will eliminate nearby detached curves over smooth bottom and where definite continuity of deeper water should not be interrupted by a closed curve, particularly in channels.

When drawing the depth curves, constant reference should be made to the boat sheet where the bottom configuration is already outlined. Although boat-sheet delineations will not necessarily be duplicated on the smooth sheet they do serve as an excellent and generally authoritative guide.

6–64 Selection of curves.—Supplemental curves specified in Table 4 should be added in shallow waters where there is considerable distance between standard curves or where the supplemental curves provide better definition of submarine features. They should also be used to delineate significant features such as least depths, tops of shoals,

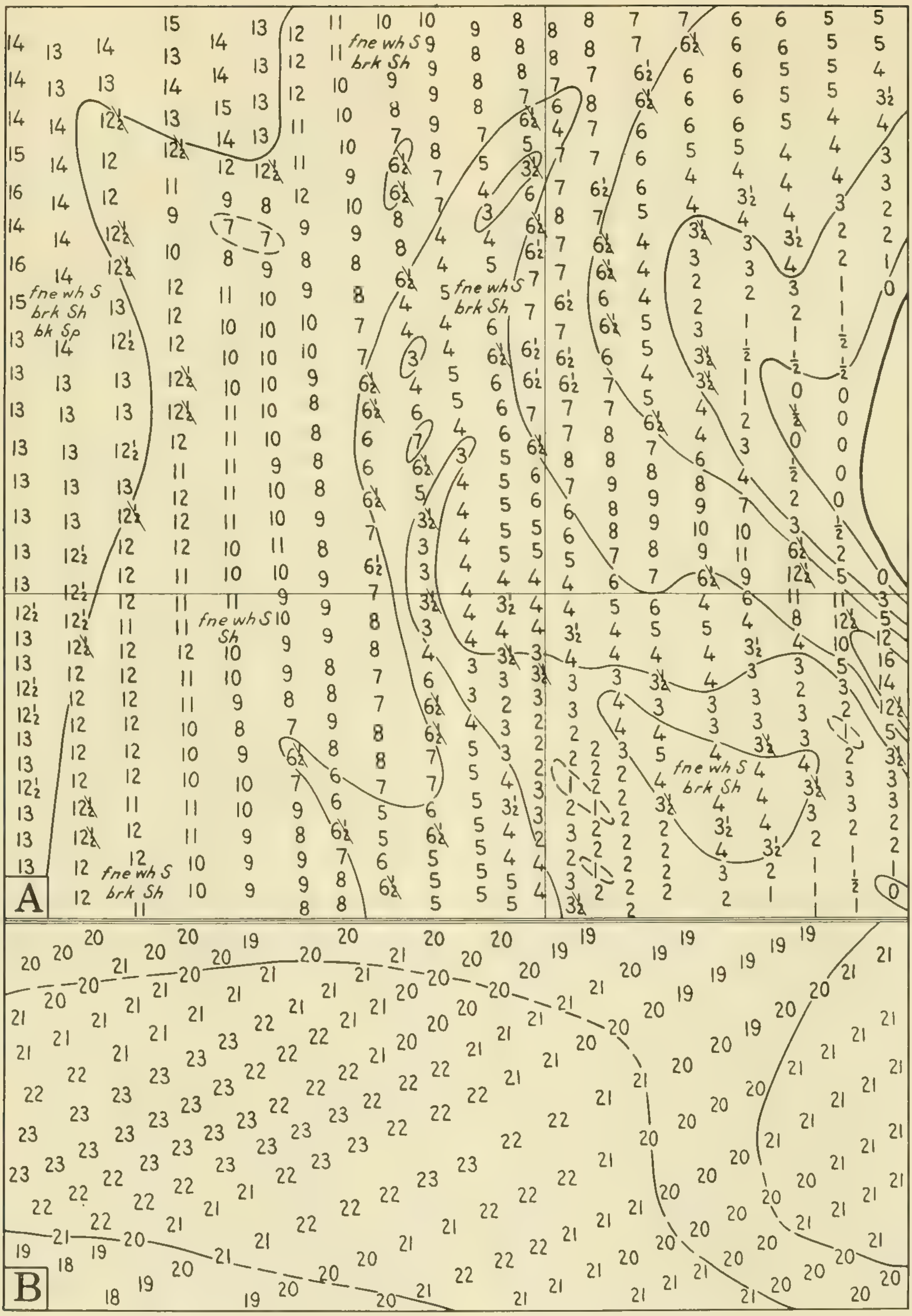


FIGURE 85.—A. Use of ½ foot soundings to smooth depth curves and to delineate continuous passages. B. 20-fathom curve—use of dashed line in deep water.

and otherwise undelineated channels and depressions. The deeper supplemental curves should be added only when irregular configurations of the bottom warrant their application. It is occasionally desirable to emphasize a shoal which is not delineated by any of the specified curves. A short-dash curve may then be drawn after verification of the survey. In inking this line it shall be the color of the shoaler curve if the delineated depth is only one unit deeper, such as 19 feet versus 18. Otherwise, the curve shall be brown and shall be inked as a solid line.

Where the curves become congested or confusing on steep slopes, the shoalest and deepest curves should be shown and the intermediate curves omitted. The shoalest curves which mark hazards to navigation and the deepest which mark the limits of channels or passages are most important. Where rocks or steep shoals rise abruptly from much greater depths one or more of the deeper curves should be omitted. Where islands, shoals, or reefs rise abruptly from much greater depths and several of the shoaler depth curves are very close to the shorelines of the islands, or edges of the reefs, the shoaler curves should be omitted.

The low-water line, the curve of zero depth, is an important foreshore feature and in some places is an important waterfront boundary. Particular care shall be taken in the delineation of this line. Inasmuch as it may be surveyed on both hydrographic and topographic surveys it is necessary to select the line to be shown on the hydrographic survey. Criteria are specified in 6–28.

6–65 Floating aids to navigation.—All aids to navigation within the area surveyed shall be shown on the smooth sheet. Floating aids shall be indicated by the appropriate aid symbol in pencil and will be inked in the proper color after verification (Fig. 79). The dot of the buoy symbol and the small circle of the lightship symbol shall be placed at the hydrographic position. Soundings at these aids are usually plotted slightly lower and out of position in order not to overlap the symbols.

Each aid shall be identified by name, classification, or number as "N7" or "BELL" and should be in agreement with charted and Light List designations. Any discrepancy in designation, description, or characteristic noted during the survey should be mentioned in the descriptive report.

6–66 Miscellaneous data.—In addition to the routine data plotted on each smooth sheet there may be various other important data to be plotted. These data may be recorded in the sounding volume or supplemental record book, on the boat sheet, or on the fathogram. They are individually discussed in the following sections.

6–67 Wrecks.—Stranded wrecks where part of the hull uncovers at low water are frequently transferred to the smooth sheet from topographic surveys, usually where a hulk is stranded near the shoreline (Fig. 79). The small circle of the symbol is the position of the wreck. These wrecks might postdate the topographic survey and be located by detached position, by reference to a sounding line, or spotted on the boat sheet. Sometimes large hulks are outlined and labeled on large-scale surveys.

Sunken wrecks are covered at low water, except that the masts may uncover. In such event the notation "masts" shall accompany the sunken-wreck symbol. Sunken wrecks are located at detached positions, and when the least depth is obtained it is plotted with notation "wreck" instead of the symbol. Offshore sunken wrecks are usually located on wire-drag surveys, and the least depths or groundings are transferred to the smooth sheet in green ink after office verification of both surveys.

6–68 Wire drag finds and clearances.—Where a wire-drag examination has been made by the hydrographic party to determine the least depth on a shoal or obstruction, the least depth found (if less than that of the hydrographic survey) shall be plotted in pencil, and a note with a leader added giving the least depth with position number

and day letter, and the clearance depth obtained.

Where a contemporary wire-drag survey has been made by another survey party, all drag finds, groundings and clearances will be transferred to the smooth sheet in green ink after office verification of both surveys.

6–69 Submerged obstructions.—A variety of submerged obstructions is encountered in hydrographic surveying, all of which must be shown on the smooth sheet. Where least depths are not obtained on unnatural features such as stubs of piles, ruins of piers or other structures, wreckage of various kinds, they shall be shown by a 1-mm circle or dashed outlined, in pencil and described. If the nature of the obstruction was not determined, the note "obstr" shall be used. Dashed lines shall be used to indicate the extension below high water of marine railways, groins, breakwaters, outfall sewers, or other unnatural features rising above the bottom.

6–70 Breakers, tide rips, eddies.—The limits of breakers, whether offshore or alongshore, should be shown by a dash line, in pencil, with the notation "breakers" added (Fig. 79). Where cuts are taken to breakers at sunken rocks or rocks awash, their intersection should be indicated by the appropriate rock symbol.

Tide rips occur in places where strong currents are found and are usually encountered in the vicinity of shoals or where the bottom is uneven. Small areas of tide rips may be shown by symbol or by legend. Where the feature is extensive the approximate limits should be outlined with dashed pencil lines and an appropriate descriptive note added. Tide rips should be qualified as heavy, moderate, or light.

Where current eddies are observed they should be shown on the smooth sheet by symbol or legend.

6–71 Tide and current stations.—Locations of tide and current stations shall be shown by blue circles 3 mm in diameter, without center dot, and legend (Fig. 79). The location of oceanographic stations or current observations by drogues shall not be shown on the smooth sheet.

6–72 Geographic names.—The final selection and placement of geographic names shall be made in the Washington Office after review and approval of the names list by the Geographic Names Section (see 7–13). Names of hydrographic features and a few topographic features shall be penciled on the sheet by the smooth plotter. Geographic names shall not be added to the smooth sheet until the soundings and other hydrographic data have been plotted. They should be placed so as to indicate clearly the features designated.

Geographic names must not obscure or confuse the soundings. On an inshore hydrographic survey, it is generally necessary to place all names inside the high-water line. Where names must be lettered in the water areas, particularly in very congested areas, a judicious placement of the name and spacing of the letters will often avoid obscuring soundings and other details.

Since the smooth sheet is the authority for charting names of all features at and offshore from the high-water line, extreme care shall be taken in the spelling and placement of the names. Instructions for lettering names will be found in 6–14. The published charts are excellent guides for placement of names and relative size of lettering for various features.

6–73 Adjoining surveys.—After the smooth sheet is completed a comparison shall be made with adjoining contemporary surveys to determine the completeness and relative agreement of hydrography. Any consistent differences in soundings and corresponding displacement of depth curves, as well as gaps in coverage, shall be stated in the descriptive report (see 7–4J). This part of the report is of significant value when the unverified survey is used for preliminary revision of the chart and is considered when assigning verification priorities. Soundings shall not be transferred to the smooth sheet by the smooth plotter.

In the event an adjoining survey is in-

complete, deficiencies at the junctions should be noted for investigation when field work on the project is resumed.

6–74 Deficiencies of smooth sheets.—Deficiencies of smooth sheets fall in three general categories: (1) Inadequate or inaccurate field data (see 1–56); (2) unrecognized or unresolved discrepancies; and (3) substandard smooth plotting as evidenced by inaccurate work or poor quality of drafting. Some of these faults are traceable to lack of training and careless supervision; others reflect the aptitude of the smooth-plotter. In order to produce a smooth sheet conforming with Coast and Geodetic Survey standards, the smooth-plotter must be thoroughly familiar with all the pertinent parts of this manual.

A list of the principal deficiencies of smooth sheets received for verification is furnished herewith. This is a partial list, and the order of listing has no significance. Smooth-plotters and supervisors should find the list most useful in review of the smooth sheet.

(a) Positions have been incorrectly plotted because the protractor was not properly adjusted or index corrections were not correctly applied.

(b) Errors in recorded angles were not detected and corrected.

(c) Misidentification of signals was not detected and corrected.

(d) Positions of signals have been incorrectly revised from sextant cuts.

(e) Sounding line positions plotted from weak fixes were not properly adjusted to conform with supplementary information.

(f) Soundings at inshore ends of lines have been incorrectly spaced to conform with change of speed or where the line began or ended on an uneven interval.

(g) Where clarification of congested areas was required soundings were poorly or improperly selected.

(h) Soundings were plotted at peaks, deeps, and abrupt changes of gradient without regard to recorded fractional sounding intervals.

(i) Soundings have been spaced at intervals which are excessively wide or unnecessarily close.

(j) The high-water line has been inaccurately transferred and various symbols carelessly drafted, particularly rock symbols.

(k) Position numbers have been carelessly placed and frequently obscured by soundings.

(l) Thin black ink has been used producing a grey shoreline and faint colored inks have been used for inking position numbers or distance circles. Poor inks should be discarded.

(m) The plotter has failed to check depths which appear erroneous or to investigate excessive differences at crossings.

(n) Improper interpretation of fathograms in areas of kelp or grass has not been corrected by the plotter.

(o) Shoreline has been transferred to the smooth sheet from preliminary rather than final photogrammetric manuscripts.

(p) Two positions, hydrographic and topographic, have been shown on the smooth sheet for an identical rock.

6–75 Inspection of smooth sheet.—After the smooth plotter has assured himself that the survey has been correctly plotted in every detail, the smooth sheet should be carefully inspected by the officer in charge of processing and the chief of party. If available, the hydrographer should also inspect the sheet. In the event that the chief of party and the hydrographer have been transferred afar to other duties before the smooth sheet is completed, the final inspection shall be made by the new chief of party who shall add a statement to the approval sheet in the descriptive report (see 7–11) regarding his inspection of the smooth sheet and accompanying records.

6–76 Report on smooth plotting.—The plotter shall maintain a rough log of his work as the plotting progresses in order that he can write pertinent sections of the descriptive report. See Chapter 7. When the smooth sheet is plotted in a processing office, the notes shall be compiled as an addendum to the descriptive report (see 7–12).

These notes should include all information

which will be of use in evaluating the smooth plotting and in verification of the smooth sheet. Unusual adjustments made in smooth plotting and deficiencies in field data should be noted where not clearly explained in the record books, such as sounding lines rejected, lines not plotted because of unresolved differences in depth, signals whose positions are questionable, and unresolved discrepancies at crossings.

6–77 Title and number.—Each completed smooth sheet transmitted to the Washington Office shall be accompanied by a copy of Hydrographic Title Sheet, Form 537, and the original shall be inserted in the descriptive report (see 7–2). The title is inked on the sheet at the office prior to final approval of the survey.

The field number (see 1–13) and the registry number (see 1–14) of the survey shall be entered in Stamp No. 42. The permanent registry number is preceded by the letter "H" denoting a hydrographic survey.

6–78 Field examinations.—The occasional small field investigations for which no specific project instructions are written (see 2–3) are registered as Field Examinations such as F.E. No. 6 (1960). Where the boat sheet is clearly legible and soundings have been corrected to show true depths, a smooth plot of the survey is often unnecessary and is not required. The survey sheet is usually cut or folded and filed with the descriptive report after verification and review.

6–79 Shipment to Washington Office.—A complete smooth sheet shall be shipped to the Washington Office only in special plastic containers supplied for this purpose. Cardboard or thin metal tubes are not satisfactory containers and are often badly damaged in transit. Shipping tubes will be furnished on requision to the Washington Office.

All records shall be forwarded by registered parcel post or express (see 7–24). Boat sheets should be sent separately and in separate mails. The smooth sheet should never be rolled to a diameter less than four inches.

Verification of Surveys

6–80 Office inspection and registration.—On receipt in the Washington Office the smooth sheet is inspected by the Chief, Hydrographic Section, Chart Division and Chief, Hydrography Branch, Coastal Surveys Division. It is registered and diagrammed on the Nautical Chart Standards and Hydrographic Survey Index Charts. It may be immediately assigned for preliminary application to charts which are currently being revised or constructed. It is preferably first assigned for preliminary or complete verification, depending on the controlling factors of priority, time, and the nature of the hydrography.

6–81 Vertical datum verified.—Before the smooth sheet is verified the sounding records are referred to the Tides and Currents Division for verification of the plane of reference for each tide station used in the reduction of soundings. If a preliminary datum used in the reduction of soundings differs more than 0.3 foot from the final adopted datum, then values in the sounding records shall be revised. A spot check of the reducers used for each day's soundings is also made. Verification and approval of the plane of reference shall be recorded in a stamp on the inside of the back cover of each volume of the sounding records.

Form 712, Tide Note for Hydrographic Sheet, shall be completed and forwarded to the Hydrographic Section for insertion in the descriptive report (see 7–13d).

6–82 Purpose of verification.—The nominal duty of the verifier is to carefully check unverified data penciled on the smooth sheet, correct any errors in the original plotting, and ink the soundings and other hydrographic data in conformance with standard cartographic practices. The work of the verifier extends beyond correcting obvious errors and providing a complete permanent record of the survey. He also has the responsibility of detecting and correcting errors of a less evident nature in the plotting, reduction or interpretation of the data which

may effect the accuracy of the hydrographic survey.

The first step in verifying a smooth sheet is to ascertain that the projection, control, and shoreline details have been checked in the field, and that all processing in the sounding records through the reduction of soundings has been checked as shown by initials in the processing stamp. The verifier then checks the descriptive report, boat sheet, and other pertinent reports for information affecting verification of the survey. He then proceeds with a methodical verification of the smooth plotting beginning with the first page of volume one of the sounding records checking the accuracy and completeness of the penciled hydrographic data. The soundings and other hydrographic data are then inked in chronological order.

Specific areas of discrepancy are sometimes revealed during verification of the final data plotted on the smooth sheet. Because of the complexity of factors affecting the plotted data, the verifier may find it necessary to review fathograms, bar checks or other echo sounder calibration data, tidal information, calibrations of electronic control systems, or sounding line adjustments in order to resolve discrepancies and properly revise the hydrographic data.

6–83 Cover sheet.—The verifier should refer to 6–42 for a discussion of the need to protect a smooth sheet. Sections of obsolete charts are satisfactory covers to protect unused portions of the smooth sheet. The cover sheets should not be shifted about while weighted with a metal protractor, sounding volumes, or other heavy objects.

6–84 Verifier's preliminary inspection.—The verifier should make a preliminary inspection of the smooth sheet to identify areas where errors may exist. These may be indicated by crossing discrepancies, unnatural bottom configuration as shown by the penciled depth curves, disagreement of depths at junctions, conflicts of depths with shoreline, or other inconsistencies which may necessitate extensive replotting of positions or soundings. The boat sheet is an independent plot of the survey and should be used as a guide in the preliminary inspection and during the detailed verification. The descriptive report and the smooth plotter's report should be consulted for information on discrepancies which were not resolved.

6–85 Replotting positions.—Since the total hydrography, including depth curves, provides a partial check on individual soundings, it is not necessary to verify the plotting of each hydrographic position of a consecutive series on line. Sufficient verification shall be done to eliminate inaccuracies in plotted positions of important hydrographic information.

All detached positions should be replotted and the positions serving to locate the least depth on important hydrographic features should be replotted. All positions which appear to be erroneous and conflict with supplementary information such as dead reckoning should be replotted. Selected positions in areas noted by the verifier in his preliminary inspection should be replotted. When the sounding lines extend into areas of weak fixes, selected positions should be replotted in order to evaluate the accuracy of the plotting. Consistently excessive differences in plotted positions may indicate that the smooth plotter used an unadjusted or uncompensated protractor. A further check on the accuracy of plotted positions is obtained by the spacing divider when soundings are being inked and any position which appears to be incorrectly plotted should be replotted.

Where the verifier has found that the original plotting of positions has been accurately done, the amount of checking should be held to a minimum.

6–86 Revised positions.—Hydrographic positions of soundings shall not generally be revised where the correct position is within the limits of the sounding numeral. Differences between the two positions should seldom exceed 1 mm. Positions locating critical soundings and other important features shall be accurately plotted and shall be revised in verification where necessary. The original

position dot must be removed in such cases in order to avoid any ambiguity. Position numbers identifying critical data, such as least depths, rocks, or obstructions, shall be moved where it is apparent that the number may be obscured in the inking of soundings or other detail.

6–87 Verification and inking of soundings.—The penciled soundings shall be checked against the sounding record and inked in black. The cartographer shall be guided by instructions contained in 6–53 to 6–60 with regard to spacing and selection of soundings and size of numerals. The soundings should generally be inked in chronological order; however, in congested areas it may be advisable to check through the complete development before inking the soundings. Where the hydrographer has indicated that some of the closely spaced lines are "not to be smooth plotted," the verifier should assure himself that no critical sounding has been overlooked (see 1–28 and 5–25).

Soundings shall be revised where they are erroneous, or are superseded by unplotted peak or significant deep soundings, or require minor revisions for depth curve delineations as specified in 6–63. Where penciled soundings are overly congested or lack clarity, selected soundings should be inked.

Since the scanning of depths on the fathograms has been verified in the field a detailed re-examination of the fathograms should not be necessary. Experience has disclosed that fathograms are sometimes inadequately check scanned; that bar-checks for specific days may differ significantly from the average used for sounding reducers; that phase changes may be erratic and not conform to the average used in the sounding record; and that interpretation of the bottom trace in kelp or grass areas or with respect to strays may be faulty. The verifier should not hesitate to examine sections of fathograms where discrepancies on the smooth sheet occur or where deficiencies in original scanning or checking affect the accuracy and reliability of the survey.

Bottom characteristics shall be inked in black using the correct abbreviations or symbols (see 6–62).

All notes in the record book shall be checked with the smooth sheet plotting. Symbols for rocks, limit lines and legends, and other penciled data shall be inked on the smooth sheet after verification of their appropriate use and conformance with cartographic standards. The verifier shall determine that all detail is represented as specified in the instructions for smooth plotting contained in this chapter. Only those revisions should be made which contribute significantly to the accuracy, completeness, and clarity of the records and the smooth sheet.

6–88 Revised depth curves.—Depth curves shall be carefully verified for completeness and accuracy of delineations. The curves shall be revised where there are significant departures from correct bottom delineations or where the selection of curves on a steep slope does not conform to standard procedure. The verifier should not overlook the delineations of curves on the boat sheet, particularly in shallow areas where the hydrographer was guided by local knowledge and by delineations on aerial photographs (see 2–16). The verifier should also refer to the photographs in specific instances where hydrographic delineations in shallow areas are incomplete or questionable.

The verified depth curves shall be inked as specified in 6–63.

6–89 Verification of shoreline and rocks.—Inked topographic detail applied during smooth plotting shall be inspected for omission and inaccuracy. Shoreline shall be revised if it is symbolized incorrectly, or if it is displaced more than the width of the inked line, and to correct errors of omission. Rock symbols shall be revised if they are excessively large or small, and, where symbols are too congested, the cartographer shall revise the penciled work to conform with standard practice as shown in Figure 81.

There are occasional differences between rock information shown on photogrammetric compilations and the hydrographic survey (see 5–67). When the hydrographer has

noted these differences and reconciled them in the field, the hydrographic data shall supersede the photogrammetric survey. When the discrepancies have not been resolved in the field the following procedures are applicable.

(a) The photogrammetric locations and elevations of bare rocks or islets shall be accepted unless there is unmistakable evidence of incorrectness.

(b) The location of a rock awash or uncovering at the sounding datum shall be carefully examined to make certain that there are not two rocks rather than an identical rock with two locations. Where the feature is visible on the photographs and the plot has been verified, the photogrammetric location shall be retained. In other instances all available data shall be evaluated and the position considered most accurate shall be accepted.

(c) The locations of sunken rocks and breakers and the notes relating thereto should be accepted from the hydrographic survey but it should first be determined that the identical feature is involved.

(d) The elevation of a rock awash should generally be accepted from the hydrographic survey because of the more definite tidal information available and the closer proximity of the hydrographic party to the feature.

The Photogrammetry Division should be notified of adjustments made which significantly affect information shown on the photogrammetric surveys.

6–90 Record of revisions.—Any revisions made in the sounding record shall be consistently entered in pencil of a color not previously used in the record. No recorded data or previous revisions shall be erased or obliterated by a rejection line. If an unplotted least depth or other critical data at one position is superseded by data recorded elsewhere in the records, a cross-reference shall be entered if not previously noted by the smooth plotter. Each position verified by protracting and all notes in the remarks column shall be check-marked.

Revisions to recorded data made during verification should be clearly explained in the sounding records and the justification for each revision should be given where it is not evident. No deviation from the original recorded data shall be made unless this appears reasonable and is supported by other evidence. Soundings should not be added to, or revised on, the smooth sheet without also showing the correct values in the sounding record.

The descriptive report shall be examined and any revisions in reported data required as a result of the verification shall be lightly but clearly entered in black pencil. These revisions will be inked in red by the reviewer.

6–91 Junctions.—A junction shall be made with each contemporary survey which has been verified, or with the preceding survey of stable-bottom areas where specified. Regardless of the stage of verification of adjoining surveys the notation "JOINS H—— (19—)" shall be placed in the junctional areas beyond the limits of hydrography, in slanting mechanical lettering 2.5 mm. high. But the note shall not be inked until junctional soundings are transferred and inked. For surveys of different scales the soundings shall be transferred from the small-scale survey to the larger. Where a sheet is surrounded by a number of sheets, always make junction on one sheet if possible. Junctional soundings should be transferred from the offshore to the inshore sheets. They shall be generally limited to one line, or equivalent, beyond the limit of hydrography on the sheet to which the soundings are transferred.

There are exceptions to the transfer of junctional soundings. They should be omitted where transferred soundings in comparable depths overlap or closely butt a plotted sounding. Critical or significant soundings, however, shall be transferred even if deletion of other soundings is necessary. Where unresolved differences in general depths exist in the junctional area, the less reliable soundings shall be omitted in overlaps, thereby effecting a butt junction. Where extensive hydrography overlaps superseded hydrography of a specified adjoining survey, soundings shall not be transferred

within the common area. In this case the superseded area shall be delimited by a dashed line and labeled "Superseded by H—— (19—)".

Junctional notations and transferred soundings shall be in color (Fig. 82, 83). A different color should be used to ink transferred soundings from consecutive adjoining surveys. The preferred ink colors are carmine red, red violet, orange, and brown in that order. Blue and green should be avoided as they photograph poorly under routine procedures. In wire-drag areas the green color shall be reserved for transfer of wire-drag soundings.

Depth curves shall be drawn so that there is a definite continuity and curves in the area of overlap shall be made to agree. This does not mean that supplemental curves on each sheet shall be added to the other.

6–92 Preliminary verification.—Complete inking of the smooth sheet can usually be accomplished during verification. Where scheduling does not permit the complete inking, authorization may be given for a preliminary verification of relatively simple surveys of uncongested areas. Under this procedure only a pattern of lines sufficient to assure the general accuracy of depths is verified and inked. Other hydrographic information to be verified and inked include least depths on important features, questionable depths not supported by other soundings, and positions of piles, obstructions, rocks awash, etc. The survey is inspected for crossing discrepancies, misplotting of sounding lines, unnatural delineation of the bottom, or other indications of errors, and the verification and inking necessary to eliminate these inconsistencies is accomplished. The depth curves are not inked and junctional soundings are not transferred to the sheet until a later date. The preliminary verification should cover all critical details essential to safe navigation and should be adequate for complete application of the survey to nautical charts. At a suitable time the verification and inking of the survey will be completed and an addendum completing the review will be added to the descriptive report.

6–93 Sheet clean up.—After completion of verification and inking of the smooth sheet, extraneous notes and marginal soiling should be removed by careful erasing, and it may be advisable to use an artgum eraser to eliminate some of the pencil graphite smear on the sheet. Care shall be taken that inked soundings are not impaired. In some congested areas on sheets occasionally penciled too dark during smooth-plotting it may be advisable to use the artgum eraser lightly before inking. This procedure permits the ink to penetrate the sheet instead of producing a thin flaky coating over the graphite-coated paper.

6–94 Verifier's reports.—Two forms are inserted in the descriptive report for use of the verifier and reviewer. The first is a 3-page check list, Form 946A, titled "Verifier's Report of Hydrographic Survey H,——" on which the verifier indicates that all essential actions have been performed. Space is provided under each heading for insertion of notes and information which will assist the reviewer, who is guided by it and abstracts pertinent parts to his review report.

The second report, Form 946, is a statistical report on which is shown the time spent in verification and review of the survey and the amount of revision required in the various phases of smooth plotting.

6–95 Plot of additional work.—Supplemental hydrography accomplished in accordance with instructions from the Washington Office is sometimes received after the survey has been smooth plotted. If this information is smooth plotted before formal administrative approval of the survey, it is verified and inked in black as part of the original survey. But when the hydrography is received after formal administrative approval of the survey, it is considered "additional work" of a specific year. In order to avoid sending the permanent copy of the survey away from the Washington Office, the smooth plotting of additional work is usually accomplished in the Verification Unit. During verification

the soundings are inked in colored ink in order to distinguish the new information from the original survey information. Supplementary information is added to the title in the same color and the sounding records are stamped "Additional Work."

6–96 Review.—The purpose of the review is to evaluate the basic quality of the survey by comparison with prior surveys and established standards for hydrographic surveying and to consider the survey in its broader aspects insofar as its application to the charts is concerned. The survey is made complete with reference to all information on prior survey sheets which need to be considered for chart compilation except as specifically mentioned in the written review.

There are three separate phases of review:

(a) Inspection of the work done by the verifier, checking anything important that was not previously checked, and examining critically any changes made by the verifier to assure that they are justified;

(b) Evaluation of the survey for compliance with project instructions and established standards for hydrographic surveys; and

(c) Determination of the adequacy of the survey to supersede prior surveys and charted information.

Evaluation of the survey includes a comparison with prior hydrographic and wire-drag surveys and charted information. Except for data from the latter source, the smooth sheet in its completed form shall show in color all supplemental data which are required to meet the standards of a basic survey. In the event the survey is deficient in accordance with the standards, a recommendation for additional work shall be made in the review report.

6–97 Reviewer's inspection.—The reviewer shall make a careful detailed inspection of the smooth sheet, including verification of new data added by the verifier. This is done systematically by beginning at the top of the sheet and inspecting all detail grid by grid. Being experienced and familiar with bottom configurations of various areas the reviewer should immediately notice any questionable sounding, curve delineation, crossing discrepancy, or other detail overlooked during verification. Excessive differences at crossings shall be investigated for the purpose of rectifying them or ascertaining the probable cause and its possible effect on other soundings. Depth curves omitted or not drawn correctly to show the proper delineation of the bottom should be added or revised. Non-standard curves should be added to emphasize bottom configuration. The application of junctional soundings and junctional notes shall be verified and depth curves in the area of overlap shall be compared for agreement. Where the project instructions require a junction with surveys by the Corps of Engineers, U.S. Army, such junctions are to be examined for adequacy but the soundings should not be transferred. Shoreline and other photogrammetric detail shall be inspected for possible omission or error and proper cartographic treatment on the survey. Deficiencies in verification found during the review should be called to the attention of the verifier who should make the required revisions.

The reviewer should not hesitate to refer to the sounding records when the obvious need arises. On some surveys occasional significant errors undetected since original recording in the sounding volumes have been found during review. Recording of least depths on the more critical features and interpretation of the bottom profile in grass and kelp areas should be examined on the fathograms.

As the review progresses, each statement in the descriptive report and in the verifier's report should be considered and each paragraph should be check-marked in red ink. Where additional evidence has altered positive statements in the descriptive report, a marginal notation citing the disposition and authority or basis for disposition should be lettered in red ink.

6–98 Wire-drag comparison.—In the event that wire-drag surveys have been made in the area, a comparison and correlation of the two surveys shall be accomplished. Ex-

cept where shoaler soundings have been found by the hydrographic survey, verified soundings, groundings, bottom characteristics, and wreck or obstruction notations shall be transferred from the wire-drag survey. They shall be inked in dark green; and the grounding circle shall be omitted. Any conflicts between hydrographic-survey soundings and wire-drag effective depth shall be resolved.

The notation "Soundings in green from H—— (19—) W.D." shall be inked in green slanting lettering in a marginal area adjacent to the transferred soundings (Fig. 83).

6–99 Prior survey comparison.—All prior hydrographic surveys shall be carefully compared with the new survey unless such comparison was made with the last previous basic survey and fully discussed in a modern review report. It is then necessary to compare only the latest prior survey with the current survey, in the common area. The comprehensive comparisons and reviews were initiated in 1932.

This comparison serves two purposes. Primarily, it is necessary to determine whether the new survey is adequate to supersede the prior surveys and to carry forward, in color, any important data needed to supplement the new survey. Also, the comparison will reveal the stable or transient character of the bottom as a matter of basic record and will serve as a guide for scheduling future revision surveys.

6–100 Prior data evaluated.—In comparing prior surveys with the new survey there may be revealed differences in least depths, spot depths, general hydrography, and other detail. Some of these differences may be due to natural or artificial changes, or to errors in plotted data. Since each significant difference must be evaluated it is necessary that the reviewer shall use competent judgment before accepting or rejecting data from any survey. He shall be familiar with procedures and techniques used in hydrographic surveying since the beginning of original surveys in 1834.

Before a significant prior sounding, rock, or other critical detail is rejected or accepted for transfer, the sounding record of the prior survey must be inspected. After verifying the reduction of a sounding, a hydrographic position, or note, the reviewer shall check-mark the recorded data in colored pencil and append his initials. Reasons for rejections shall be noted therein unless they are obvious. Rejected data on the prior smooth sheet shall be neatly crossed with a single colored line accompanied by a short rejection notation, date, and reviewer's initials. Red ink shall generally be used. The prior data shall not be erased as they are recorded authorities for charted and otherwise disseminated information.

6–101 Retention of prior data.—Any important data on prior surveys which have not been verified nor disproved by the new survey shall be carried forward to the new survey in colored ink (Fig. 83). A notation in the same color, usually red, "from H—— (year)" should be placed nearby, or in a marginal area where a group notation should read "Detached soundings in (color) from H—— (year)." Slant-line lettering shall be used.

The locations of, and least depths on, all important shoals, rocks, and other obstructions shall be compared. Where a difference in position is found for an identical feature, the strength of the respective methods of location shall be evaluated and the stronger one accepted. Where the least depth on the feature is not verified nor disproved by the new survey, the sounding shall be transferred from the prior survey. Both soundings should be shown, and each shall be displaced slightly if necessary. It may not be possible to plot both soundings in a congested area, in which case only the shoalest sounding shall be shown.

Occasionally it is necessary to transfer a group of soundings from a prior survey to complete the hydrography in a gap or small unsurveyed area of the new survey. Similarly it may be necessary to supplement the survey by transferring ledge, reef, or rock delineations where both the new hydro-

graphic and photogrammetric surveys are deficient in these respects.

It will frequently be found that rocks shown on a prior hydrographic or topographic survey have not been verified by the new survey or have been located in a slightly different position, or are of a somewhat different character. In the disposition of such cases all available information should be consulted and the following rules should be followed:

(a) Where the position of what is presumably the same rock differs on the new and the prior survey, the new position should be accepted as correct.

(b) Where an adequate examination, made by the new hydrographic or topographic survey in the vicinity of a rock or rocks, fails to disclose the existence as shown on the prior survey, the recommendation made by the hydrographer regarding its disposition, should be followed.

General statements in a descriptive report, particularly of a topographic survey, that certain rocks on old surveys could not be found should be accepted only as proof that such rocks are not bare rocks. They should be transferred either as rocks awash or as sunken rocks, depending on the circumstances in each particular case.

(c) Bare rocks on a prior topographic or hydrographic survey, that are not shown or disproved on the new hydrographic or topographic survey should be carried forward as rocks awash.

(d) Rocks awash on a prior survey that are shown as sunken rocks on the new survey should be considered as rocks awash unless there is information on the new survey to show that the rock was not visible at low tide. In such cases the rock awash symbol should be shown in black ink on the new hydrographic survey and a note made in the sounding record.

(e) Sunken rocks on prior surveys, if not disproved by the new survey, should be carried forward with caution. On some prior surveys a sunken rock symbol was used to indicate a rocky bottom area and not necessarily individual submerged rocks dangerous to navigation.

(f) In general, the delineation inside the low-water line should be accepted as correct on the new survey, except that isolated rocks awash shown on a prior topographic survey, that are not located or disproved on the new survey, should be carried forward in color.

6–102 Geographic datums.—It is essential that the reviewer shall correctly identify the geographic datum to which a prior survey was referenced and make adjustments where necessary to permit comparison at the datum used in the most recent survey.

During the early years of the Bureau's operations many detached triangulation systems existed in the United States, each based on independent astronomic observations within the system. Hydrographic and topographic surveys within the areas were consequently based on independent datums depending on the triangulation in use. With the completion of the first transcontinental arc of triangulation the various detached systems were connected and a coordinated system based on a single geographic datum was established for the whole country. Station MEADES RANCH in central Kansas was selected as the basis for this single geodetic datum and in 1901 the adopted datum was officially named the United States Standard Datum. In 1913 Canada and Mexico adopted this datum which was changed in name only to the North American Datum.

In 1927 a unified adjustment of all first order triangulation in the country was begun and, as a result, the North American Datum of 1927 was adopted. This datum has been extended into areas in Alaska where previously several independent datums were used. Modern hydrographic surveys in waters bordering the continental United States are now made on this geographic datum. Surveys in the waters of the Hawaiian Islands are based on the Old Hawaiian Datum.

Many prior surveys list the geographic position of a triangulation station positioned within the surveyed area. It was frequently inked in the lower margin, but the datum is not always indicated. On later surveys

both the geographic position and geographic datum are listed.

For a more detailed discussion on datums, the spheriods adopted for survey and chart projections, and the earth's geoidal surface, refer to the discussion, "Geographic Datums of the Coast and Geodetic Survey," by A. L. Shalowitz, published in the Field Engineers Bulletin No. 12, December 1938, U.S. Coast and Geodetic Survey.

6–103 Datum ticks.—Before comparing surveys of various years the geographic datums must be correlated. It shall never be assumed that an unlabelled projection on a survey is on a certain datum. The difference in datums, if any, shall always be determined before comparing surveys or transferring data.

The U.S. Standard or North American Datum is shown by a complete projection in color on many of the older surveys. Many others show only one or two marked projection intersections (ticks) on the above datum or the NA Datum of 1927 (Fig. 86). These conditions reflect the specific needs and time available for application of the datum correction. If the prior survey does not show the NA 1927 datum, this datum shall be established. At least three widely separate triangulation stations on the sheet are selected, whose geographic positions on the NA 1927 Datum are available. Two

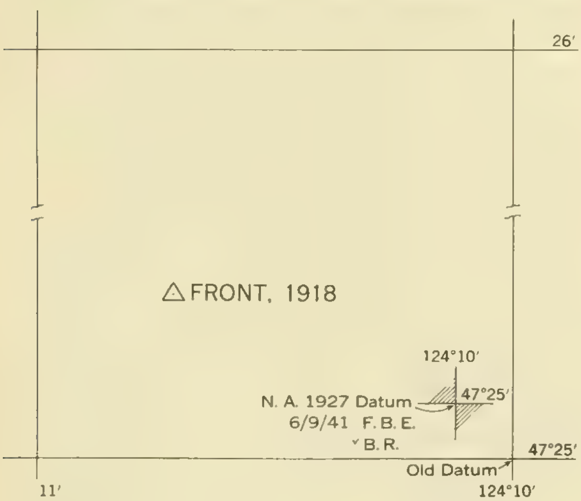


FIGURE 86.—Change of datum of survey sheet.

methods can be used for determining the datum differences.

In the first, the geographic position data used in plotting the original survey are determined from old registers of the Nautical Chart Branch, or records or publications of the Bureau. The mean of the differences between values on the two datums is the correction to be applied to the projection on the survey. The differences for the three stations should nearly equal each other. If a wide variance is found, an investigation should be made for possible errors in computations or for failure to identify common stations on the two datums. The position of the NA 1927 Datum relative to the original projection can be determined by back plotting the NA 1927 values from one of the triangulation stations or by following the rule that if the latitude (N) and longitude (W) on the old datum are greater than the corresponding values on the new datum, the new projection will be north and west, respectively, of the old projection. If the old values are smaller than the new ones, it will be the south and east.

The second method is applicable where the geographic position data used in plotting the selected triangulation stations on the prior survey are not available. A graphic method of determining the datum differences is used. Arcs based on the NA 1927 values of latitude and longitude are swung from the selected triangulation stations shown on the survey and tangents to the arcs are drawn parallel to the projection. The datum differences are scaled in meters between the tangents to the arcs and the original projection. An average of the differences is used in plotting the datum tick.

In applying datum ticks to old surveys extreme care shall be taken in determining the proper relation of the NA 1927 datum to the original projection. Distortion in the original projection shall be measured and properly applied to all distances measured or plotted. Plotting of the datum tick in colored ink shall be verified by another person. Both shall initial and date the plotting beside the tick. The tick shall be identified by

values of latitude and longitude and shall be labelled NA 1927 Datum.

6–104 Chart comparison.—The survey shall be compared with the latest print of a large-scale chart or current chart drawing of the area for the purpose of evaluating the charted data and adequacy of the survey to supersede all prior surveys for charting purposes. The comparison should be made with the largest scale chart of the area unless the chart of next smaller scale was revised first and is the better medium for comparison. Each charted sounding and individual item within the area of the hydrographic survey shall be compared and checkmarked on the chart or an overlay of the drawing.

The comparison is a relatively simple procedure when the common area involves only a comparison of soundings previously made with prior surveys (see 6–99). The most complicated comparison occurs in areas of very irregular bottom and the chart includes data from advance information from the new survey in the form of chart letters, boat sheet hydrography, unverified and unreviewed hydrography, Corps of Engineers surveys, Coast Pilot field inspection reports, and miscellaneous reports from other sources.

In the event that the comparison and review reveal an uncharted danger or condition important to navigation, the reviewer shall immediately inform the Chief, Nautical Chart Compilation Section. The data shall be indexed on the Nautical Chart Standards and considered for inclusion in the next Notice to Mariners regularly published by the Navy Hydrographic Office.

Significant charted soundings or features which have not been previously disposed of and which conflict with the reviewed survey or which should be retained on the chart as supplementary data, shall be evaluated and recommendations made for their disposition. In general, comparison with surveys of other organizations should be restricted to charted information only. Only in exceptional cases is information from such sources actually carried forward to the new survey.

Controlling depth notes charted from surveys made prior to the present survey should be compared with the new survey. Controlling depth notes charted from surveys subsequent to the present survey supersede the present survey information and a comparative evaluation is not required.

The aids on the latest aid proof should be compared with the survey to see whether they adequately mark the feature or serve the purpose intended. New positions of shoals found in the area or channels not adequately marked by the buoys shall be noted. The charted and survey positions of fixed aids to navigation should be compared.

6–105 Review report.—At the conclusion of the review a report shall be prepared for insertion in the descriptive report. The report is a summary of pertinent facts relating to the survey and the detailed comparisons made with prior surveys and other chart source material. Specific evaluations are given covering the adequacy of the present survey to supersede prior survey data and charted information. The report should serve as a guide to the chart compiler and form a basis for instructions for additional field work when considered necessary for completion of the survey. Sections and subject matter of the report shall be in the order and form indicated in the following sub-sections:

1. Description of the area.—The area should be described briefly. State the location, general character of the area surveyed, and nature of the submarine relief.

2. Control and shoreline.—When the origin of the control is adequately described in the descriptive report a short reference to the appropriate section is sufficient. Include supplementary information resulting from verification and review when necessary.

The source of shoreline data shall be stated, specifically identifying the advance or final photogrammetric manuscripts where these were used in the final shoreline comparison.

3. Hydrography.—A summary evaluation of the hydrography should include specific statements regarding agreement of soundings at crossings, completeness with which

depth curves could be drawn, and conflicts with photogrammetric surveys. A statement should also be included regarding the adequacy of development of bottom configuration and least depths. Any significant deficiencies shall be described.

4. **Condition of survey.**—Comments should be made regarding deficiencies in field work procedures, sounding records, descriptive report, or field plotting. Cases where procedure is definitely wrong or fails to comply with the Hydrographic Manual should be specifically mentioned. Criticisms from the verifier's report or the report on smooth plotting that are found justified and should be brought to the attention of the hydrographer should be included. Should the condition of the survey be found to be satisfactory, only a simple statement need be made that the field plotting, records and reports are adequate and conform to the requirements of the Hydrographic Manual.

5. **Junctions.**—Adjoining surveys shall be reported by number and year, stating their relative position to the present survey. The junctions shall be evaluated and discussed with respect to adequacy. Important discrepancies that cannot be reconciled shall be described and probable causes stated. Where a butt junction must be made because of differences in depths, the condition shall be specifically described.

6. **Comparison with prior surveys.**—The results of comparisons of prior surveys with the new survey shall be summarized in a brief introductory paragraph. Changes in the shoreline or bottom configuration and depths should be described. State whether they are due to natural or artificial causes or to less detailed and accurate methods employed in the prior surveys. Differences in depths caused by dredging shall be mentioned. Details shall be discussed under prior survey headings. For coordinated discussion, these surveys should be grouped according to age except when changes appear to be progressive and can be described more conveniently by grouping together surveys of several periods. In each discussion there shall be a statement to the effect that the prior surveys are superseded, except that the statement may be qualified because of the retention of specified details. As mentioned in 6–99, it will not be necessary to discuss original surveys if comprehensive comparisons were made during reivew of the latest prior survey.

(a) **Wire-drag surveys.**—Discuss comparison with wire-drag surveys separately. This item shall include contemporary wire-drag surveys which have been reviewed and prior wire-drag surveys which may cover the area or a portion of it. Where no conflicts occur between the present survey depths and the effective depths of the wire-drag surveys, only a simple statement need be made to that effect. Conflicts occurring as a result of changes in the bottom should be recognized as such. However, wire-drag surveys are not superseded by ordinary hydrographic surveys.

7. **Comparison with chart.**—The chart number and print or drawing date shall be placed beside this heading for ready reference. Discussion of the comparison shall be subdivided as follows:

(a) **Hydrography.**—State the origin of the charted hydrography and proceed with a discussion and listing of data to be considered specifically in subsequent chart revision. Most of the charted data will already have been considered in the comparison with prior surveys. Attention need be given only to charted data from chart letters, advance copies of boat sheets, U.S. Coast Guard and U.S. Hydrographic Office Notices to Mariners, Corps of Engineers blueprints, or other sources. Where charted data from sources other than Bureau surveys have not been adequately disproved by the present survey and should be retained on the chart a specific recommendation to that effect should be made. The discussion should be concluded with a statement as to the adequacy of the present survey to supersede the charted hydrography.

(b) **Controlling depths.**—The controlling depth notes are usually based on data furnished by the Corps of Engineers. The result of the comparison with notes dated prior

to the date of the present survey should be discussed. Controlling depth notes dated subsequent to the present survey supersede the present survey information and should be so identified.

(c) **Aids to navigation.**—The adequacy of the charted positions of aids to navigation in marking the features or serving the purpose intended should be stated. Where shoals and channels have shifted in position and are not adequately marked by the charted buoys, or a new unmarked danger is noted, a definite recommendation should be made. Except for a fixed aid moved in its official position subsequent to the present survey, differences between the charted and present survey position of fixed aids to navigation should be noted.

8. **Compliance with instructions.**—A brief statement shall be made that the survey adequately complies with the projection instructions, unless there is a significant exception to be noted.

9. **Additional field work.**—The survey shall be evaluated as an adequate, good, or excellent basic survey and a statement shall be made that additional field work is or is not recommended. If additional field work is recommended, each item or area shall be clearly described unless reference can be made to specific discussions in the report. Where further work is desirable, it will usually consist of examination of shoal indications or questionable charted information, disposal of discrepancies, and further development of outstanding oceanographic features or inadequately developed areas on the survey.

6–106 Final inspection.—The Chief, Hydrographic Section, shall make a final critical inspection of the survey for the purpose of gaining an overall picture of the survey with regard to coverage, delineation of depth curves, critical depths, cartographic symbolization, and verification or disproval of charted information. The review report is examined to see that all pertinent facts have been adequately and clearly presented, and that significant actions taken during the review and the recommendations included in the report are correct and adequate. The review report is typed and inserted as an addendum to the descriptive report.

6–107 Administrative approval.—The smooth sheet and descriptive report shall be submitted for approval by the administrative officers who direct the field survey operations and charting of the surveys. Their approval shall be indicated by signatures on the last page of the review report.

Copies of the approved review report shall be forwarded to the Coastal Surveys Division, the chief of party and hydrographer responsibile for the survey, and the smooth plotter.

6–108 Preparation of presurvey review.—The Hydrographic Section shall prepare a presurvey review of charted data in advance of field surveys. Although the hydrographer will have copies of the latest large-scale charts and will be furnished copies of pertinent prior surveys, an office review of all survey records and chart information received from other sources is an invaluable aid to all phases of hydrographic survey operations. The reviewer shall furnish any information which will benefit surveying and charting. He shall consider reviews of the latest surveys but usually need not refer to surveys which have been superseded.

The reviewer shall compare prior surveys with the largest scale chart or charts of the project area. Any questionable hydrographic data and important undeveloped depths shall be encircled on the chart after examining the records and verifying the plotting of the original information on the survey if not previously verified. Charted data which obviously must be transferred to the boat sheet (see 5–15) and verified in a revision survey shall not be considered. These include charted wire drag clearances and least depths on shoals and submerged rocks when these data are verified on prior surveys. But reported shoals, rocks, wrecks and piling shown on the chart shall be encircled. Pertinent data on source material indexed subsequent to the print date of the chart shall be considered.

A condensed report shall be placed as an inset on the chart for unit reproductions for field and office use. The report shall include a general statement on the extent of the review, and character of the area. Either a statement or legend shall be included to explain chart markings. Each circle should be numbered and its feature described under the same number in the report, unless a short notation beside the circle furnishes adequate information. It is particularly helpful during survey investigations if essential information on reported features is included in the presurvey review.

The presurvey review shall be dated and signed, and inspected by the Chief, Hydrographic Section. It will be filed for use during final review of the new survey. Should any important information affecting current charting be revealed during the presurvey review, the Chief, Nautical Chart Compilation Section, shall be so informed for reasons stated in 6–104.

7. REPORTS AND MISCELLANEOUS

7–1 Descriptive report.—A separate descriptive report shall be written and submitted to accompany each hydrographic sheet. The purpose of the report is to supplement the smooth sheet and sounding records by information that cannot be shown graphically on the smooth sheet or to direct attention to important results. It outlines the conditions under which the work was done and discusses factors affecting accuracy of the results. It should be written with a view to assist the cartographers who verify and review the survey and chart the results. It serves to index all records and reports which are applicable to the survey, and to give, in concise form, information on certain standard subjects. The descriptive report should, therefore, be written with these purposes in mind. General statements, as well as the detailed tabulation of self-evident data, such as inshore rocks and shoals, or rocks or coral heads that are encircled by depth curves, serve no purpose and should not be included.

A daily journal should be kept by the hydrographer, as a satisfactory descriptive report cannot be written from memory nor by an individual having no personal knowledge of the field work unless he has such a carefully prepared journal.

Notes made on the boat sheet to supplement the daily journal shall, if applicable, be incorporated in the descriptive report.

In surveys of large extent or of a complicated nature, it may be advisable to write special reports on certain phases of the work covering the entire season or area. A cross reference to each of these should be made under the proper heading of the descriptive report.

The descriptive report of a limited isolated survey should include all data, computations, forms, etc., ordinarily mailed as separate reports, with the exception of those specifically required to be submitted separately, such as coast pilot notes and landmarks for charts.

The various data which are required on separate sheets shall be arranged before and after the text in the sequence described herein.

Form 504, descriptive report, shall be used as the outside cover sheet, all of the appropriate entries being made.

7–2 Title sheet.—Titles shall not be placed on hydrographic sheets by the field party. But the information for the title of a survey shall be furnished on Form 537, Hydrographic Title Sheet. A copy shall be forwarded attached to the smooth sheet, and the original shall be inserted in the descriptive report. Entries shall be made in all applicable spaces on the form. The title of a hydrographic survey must clearly indicate the limits of the survey and agree with the entries in the sounding records. The information shall include the specific locality, year of the survey, the names of those persons actually in charge of sounding, the depth unit, and the plane of reference.

7–3 Index of sheets.—Where there are a number of sheets in one project, a copy of the sheet layout at a reduced scale should be included in the descriptive report. The subject survey should be indicated on the sketch and the adjoining sheets identified by registry numbers. The scale of the index is immaterial but the size of the paper or drawing should be 8 by 10½ inches. Photostat or ozalid prints of the boat sheet layout will be furnished by the Washington Office on request.

7–4 **Descriptive report text.**—The text of the descriptive report shall be typewritten on letter-size paper with a left-hand margin of 1¼ inches for binding. Only one copy shall be forwarded with the records unless the sheet is to be plotted at a processing office, in which case the report shall be forwarded in duplicate.

Each text shall be titled "Descriptive Report to Accompany Hydrographic Survey H—— (Field No. ——)" (insert registry and field numbers). The scale and year of the survey, the names of the survey vessel or party and the chief of party shall be shown.

The text should be written clearly and concisely. No information required for complete understanding of the records shall be omitted but verbose explanation of details shall be avoided. When reference is made to a hydrographic feature on the smooth sheet, the latitude and longitude of the feature shall be given. In order to provide uniformity of reports, the text shall be arranged under the following lettered headings and in the order appearing here.

A. **Project.**—Include the project number and date of original instructions, and the dates of any supplemental instructions and letters which are pertinent.

B. **Area surveyed.**—Briefly describe the area covered by the survey and the adjacent coast. State the general locality, approximate limits, and inclusive dates of the survey. If the survey makes a junction with prior surveys, mention these by registry numbers, scales, and dates; and list by registry or field numbers all contemporary surveys with which junction is made.

C. **Sounding vessel.**—List all ships and/or launches used to obtain the soundings and the colors used to identify the work of each unit, except when all hydrography is accomplished by the ship named in the title.

D. **Sounding equipment.**—Identify by types and serial numbers all echo-sounding instruments used, state the type of other sounding equipment used, and the general area or depths in which each was used. Briefly describe method used for determining echo sounder corrections. Discuss any faults in equipment which affected the accuracy of the soundings.

E. **Smooth sheet.**—State how and where the smooth sheet projection was made. When the boat-smooth sheet method of plotting is used, state the maximum probable error of positioning resulting from final computation of calibration data. If the smooth sheet is plotted by use of film positive copies of the boat sheet, state the percentage of positions protracted directly on the smooth sheet. Discuss the extent of adjustments required in transferring positions.

F. **Control.**—State the method or methods of horizontal control used and define the areas in which each was used. Explain in detail any unusual or substandard methods. List the shore stations used for electronic systems of control and state how each station was located. List graphic control or other planetable sheets by field or registry number. List the photogrammetric compilations used for transfer of signals. Identify compilations which are advance manuscripts and give the print date if known.

G. **Shoreline.**—Give the source of shoreline details listing all topographic sheets or photogrammetric compilations used unless they are listed in F. State whether the transfer of shoreline and topographic details has been verified.

If any of the shoreline or topographic details were found to be inaccurate or to have changed since the date of the original survey and were revised by the hydrographer, identify the parts revised and state the methods used. Any discrepancies between photogrammetric and hydrographic locations of offshore details must be explained in detail.

If the low-water line is not defined by the soundings, describe the conditions which prevented this.

H. **Crosslines.**—State the percentage of crosslines run and discuss any discrepancies at crossings. Explain methods used to reconcile differences at crossings.

I. **Junctions.**—Discuss the agreement or disagreement in depths at junctions with surveys listed in B. If an adjustment is re-

quired, make a recommendation as to how this should be done.

J. Comparison with prior surveys.—Each item in the presurvey review which is within the limit of the survey must be listed and discussed. State whether the existence of the feature was verified or disproved. Make a specific recommendation as to whether the feature should be charted, moved in position, or deleted from the chart. The least depth obtained on submerged features should be given.

In addition, compare the results of the new survey with those of prior surveys of the area, identifying the latter by registry numbers, dates, and scales. State the general agreement or disagreement between the new and the old surveys, and give conclusions reached as to the reasons for differences found. List any other features or depths on prior surveys whose existence has been disproved and which should be deleted from the charts. Include bare rocks as well as subsurface features and depths.

Compare the new survey with any surveys in the area by the United States Corps of Engineers. The Engineers surveys should be identified by date, scale, and sheet number, and should be forwarded with the smooth sheet.

K. Comparison with the chart.—Compare the survey with a copy of the largest scale chart of the area, identifying the chart by number and print date, and give similar information, without duplication, to that required for prior surveys. Charted features bearing the notation "reported," "ED," or "PD" must be specifically mentioned and appropriate recommendations made as to future charting.

Tabulate and describe the *important newly found dangers* to navigation giving the latitude and longitude of each and the least depth on each with its position number. Mention specifically each danger reported to the United States Coast Guard.

Dangers and shoals found or investigated by wire drag should be listed separately. Least depths and clearances obtained shall be stated.

L. Adequacy of survey.—State whether the survey is complete and adequate to supersede prior surveys for charting. Identify any part of the survey that is incomplete or substandard in any way.

M. Aids to navigation.—Refer to the separate report on Landmarks for Charts and Fixed Aids to Navigation. If there has been correspondence with the United States Coast Guard regarding the location or establishment of floating aids in the surveyed area, references shall be made thereto. It is not necessary to list each floating aid by geographic position and characteristic. However a comparison shall be made with data in the latest Light List and with the largest scale chart of the area. The hydrographer should state the results of this comparison, and indicate whether or not the aids adequately serve the purposes for which they were established.

List all unofficial aids to navigation not shown in the Light List stating their purpose, whether maintained and by whom, and whether such maintenance is seasonal or not, if this is known. Give the position and description of each aid and the date of establishment if known.

List all bridges and overhead cables not shown on the chart. State bridge and cable clearances if measured by the survey party. Mention any submarine cables and pipelines and ferry routes in the area and give the positions of their termini.

N. Statistics.—Give the total number of positions and nautical miles of sounding lines for each ship or launch employed on the survey and the total area in square nautical miles for the sheet. Tabulation of statistics for each day is not required.

A summary of other statistics concerning the survey may be included such as the number of tide, current, oceanographic, and magnetic stations, and the number of bottom samples obtained, etc.

O. Miscellaneous.—Include in this section any information of scientific or practical value resulting from the survey and not covered in previous sections. Where silted areas are detected the discussion should in-

clude the size of the areas, apparent thickness, and reference to typical profiles by date and day letter. Unusual submarine features such as mounds, valleys, and escarpments should be described. If special reports have been submitted on such subjects, they should be referred to by title and author.

P. Recommendations.—If any part of the survey is considered inadequate for charting, submit a recommendation as to additional field work required and the methods to be used. Include recommendations for further investigation of unusual features or sea conditions of interest and in excess of charting requirements.

Q. References to reports.—List all reports, records, and forms not included in the descriptive report or records of the survey which are necessary for a complete evaluation and understanding of the survey records, and which have been submitted separately. Give the title of the report and the date on which it was forwarded to the Washington Office.

7–5 **Separates following text.**—Various tabulations and kinds of information are required on separate sheets of paper inserted in the descriptive report. Each of these that is applicable shall be furnished and inserted in the order in which it is described in the following sections.

Beginning with the first page of the text, it and the attached inserts shall be numbered consecutively, ending with the approval sheet which is always placed last.

Other forms and reports will be added to the report in the Washington Office when the smooth sheet is verified and reviewed. Therefore, the report should be secured in the cover with removable staples.

7–6 **Tide note.**—A tide note shall be attached to the descriptive report for each hydrographic survey. The location, including the latitude and longitude, of each tide station used or tidal zone established for reduction of soundings plotted on the sheet shall be given. If more than one station was used, the tide note shall define the limits of the area in which each was used. The note shall state the height on the tide staff at each station corresponding to the plane of reference and whether any corrections for differences in time or height were applied to the observed tides. If the hourly heights were furnished from the Washington Office the tide note should so state. The time meridian used at each tide station shall be stated.

7–7 **Geographic name list.**—An alphabetical list of all geographic names penciled on the smooth sheet shall be prepared separately and inserted in the descriptive report. No other information should be included with this list except a reference to special reports on geographic names (see 2–42).

7–8 **Abstract of corrections to echo soundings.**—An abstract, in tabular form, of the velocity corrections which are applied to echo soundings shall be included as a separate entry in the descriptive report. A reference should be made to the special report on corrections to echo soundings submitted for the project. The abstract shall show the dates, vessels, and instruments to which the corrections apply. If the same corrections apply to more than one survey, a copy of the abstract shall be included in the descriptive report for each survey.

7–9 **Abstract of corrections to distance measurements.**—When all or part of the survey is controlled by an electronic distance measuring system, an abstract of corrections applied to the measured distances shall be inserted in the descriptive report. The dates, vessels, and equipment to which the corrections apply shall be clearly shown. Carbon copies of applicable tables in the special report on the same subject are adequate for this purpose.

7–10 **List of signals.**—An alphabetical list of stations (signals) used on the survey shall be typed on a separate sheet and inserted in the descriptive report. The list shall show the name as used in the hydrographic survey and the authority for the

position. The list should be in the following form:

List of Stations on H–8455 (SO–10–1–59)

Name used in Hydrographic Survey	*Origin of Station*
Ave	T–11384.
Box	T–11386.
Cup	SO–A–56.
Tank	Punta Gorda Beach, Tank, 1955.
Vel	Vol. 1, Page 3.
Wit	T–11385.
Yet	H–8142.

When a triangulation or traverse station has been used, the complete name with the year of establishment is necessary.

7–11 Approval sheet.—The chief of party shall furnish on a separate sheet of paper, attached to the descriptive report, a signed statement of approval of the survey. This shall serve as a general approval of the smooth sheet and all accompanying records. It should include a statement as to the amount of personal supervision of the field work and the frequency with which he examined the boat sheet and other records, whether the survey is complete and adequate, whether additional field work is recommended, and any additional information not included in the descriptive report that may be of assistance in verifying and reviewing the survey.

When a hydrographic sheet is transferred elsewhere for completion, as to a processing office, approval shall be made of only that part of the work which has been completed. If the completed smooth sheet is returned to the chief of party for examination prior to transmittal to the Washington Office, his approval of the smooth plotting should then be added.

7–12 Processing office notes.—When a hydrographic survey is smooth plotted in a processing office, the smooth plotter shall supplement the descriptive report, under pertinent headings in 7–4, as necessary to accomplish the intent of the report and without duplication. The supervisor of the smooth plotters and the officer in charge of the processing office shall review the completed smooth sheet prior to its transmittal to the Washington Office and indicate his approval by endorsement of the report.

7–13 Additions at Washington Office.—In the interval between receipt of the hydrographic sheet and accompanying records at the Washington Office and the final approval of the survey by the administrative officers, certain forms and reports are added to the descriptive report. These include the following:

(a) Geographic names sheet.—This form is used to list names approved for charting by the Geographic Names Section (see 6–72).

(b) Records accompanying survey and office statistics.—On this form an entry is made of the records accompanying the survey, such as the number of boat sheets, sounding volumes, special reports, etc. On the same form there are included certain office statistics incident to the verification and review of the survey (see 6–94).

(c) Record of applications to charts.—On this form is shown the dates when data are transferred from the survey to the chart, the charts affected, the name of the cartographer who did the work, and whether before or after verification and review of the survey.

(d) Tide Note, Form 712.—This form is completed by the Tides and Currents Division and is usually a verification of the tide note inserted by the field party. Any discrepancies in zoning or datum used to reduce the soundings are noted.

(e) Review report.—The final report on verification and review of the survey as written in the Review Section of the Nautical Chart Branch and signed by administrative officers of the Chart Division and Coastal Surveys Division is inserted (see 6–104).

(f) Section of chart.—A section of a nautical chart is inserted on which the limits of the survey are outlined.

7–14 Investigation of geographic names.—A detailed investigation of geographic names shall be conducted while surveys are in progress to furnish data for the report on geographic names (see 2–41 to 42). Charted names and those in the Coast Pilot

should be checked against local usage. If a name is well established through long use on maps and charts and is appropriate it should be adhered to even though found to differ from local usage, especially if the feature is of more importance to navigation than it is to the local inhabitants, or if the local name is an awkward or difficult one.

When published names differ from local usage, the investigation should disclose how well established the local name is and the origin of it. Dual names for the same feature are referred to the United States Board on Geographic Names for decision. Such cases should be documented as to sources and history and should be accompanied by a recommendation as to which name should be accepted.

Map sources which are easily accessible to the investigator should be consulted for geographic names, but an exhaustive search is not required. The standard quadrangle maps of the United States Geological Survey, and official state or county maps should be consulted. Copies of the latter, when obtainable, should be forwarded to the office if necessary to support recommendations for new names or revision of names.

When map sources are not available, the inhabitants of the area must be consulted to determine the names used locally. Only residents who have been long established in the area should be considered as authorities. Names of hydrographic features should be obtained from persons living near the water or who have interests connected with the water. Judgement is required to evaluate the information obtained and to gage the reliability of the individual witnesses. It is particularly important to determine the correct spelling of names obtained from individuals. Legal documents will be found useful when verifying the spelling of unusual names, or names which may be spelled more than one way.

It is necessary to delete a charted name when the feature no longer exists. The name should never be transferred to a similar feature in the vicinity. A typical example is where a previous inlet through a barrier beach has been closed permanently and another similar inlet breaks through several miles away. This does not apply to an inlet or point of land which has migrated from its original position.

7–15 Preliminary review of geographic names.—When photogrammetric parties operate in advance of the hydrographic survey, the photogrammetrist will make an investigation of geographic names to be applied to each photogrammetric compilation. In order that this work shall not be duplicated by the hydrographer, the Geographic Names Section will furnish a list of names which fall outside the limits of the compilations or which require further investigation to reconcile discrepancies.

A chart, or charts, of the area will be furnished containing all names taken from published sources. These are considered base-map names. Any disputes which exist among published names will also be shown. Part of the hydrographer's work is to check these names with local sources and submit a report on his findings. Many names are so well established that a field check is unnecessary. These names are indicated by a check mark or are underlined, usually with green ink.

A copy of the chart should be returned with the report. Verified base-map names should be inked in black. New names or disputing names should be inked in red. Disputing names should be in parenthesis near the names they dispute.

7–16 Assignment of new names.—In an unpopulated area which is being thoroughly surveyed for the first time on a large scale, names may be needed for previously unnamed features. When such features, in the opinion of the hydrographer, are important to navigation and will need to be referred to by navigators, in the Coast Pilots, or elsewhere, he should list them in the descriptive report, recommending suitable names.

So far as practicable, names of the type already in use in the area and that have some historic, incidental, or descriptive significance should be selected. Names with a

historic significance are preferable and a little research will often disclose satisfactory names connected with the history or traditions of the place, some characteristic of its inhabitants, or some outstanding happening in the vicinity. Descriptive names are generally unsatisfactory because most of them have been used repeatedly and their assignment to new features only adds to the confusion instead of providing names which identify as intended. Such names as Grassy Point, Round Island, Green Island, Mirror Lake, and many other similar names are in such frequent use that they provide no useful identification. When the form or character of the feature is so unusual that a certain descriptive name identifies it beyond doubt then that name should be recommended.

7–17 Standard nomenclature.—The following terminology should be used in referring to features that conform with the definitions, or when recommending names for previously unnamed features. The definitions are intended to standardize usage in surveying, charting, and descriptive or other reports. The glossary has no legal significance, but reflects accepted standards approved by the Board of Geographic Names. Some terms are peculiar to a region and shall be accepted when they occur in well established local use. For example, a minor stream is frequently called a "branch" along the south Atlantic coast; and a small low island may be called a "key," "cay" (English) or "cayo" (Spanish).

A. Coastal and Other Visible Features

atoll. A coral reef generally circular in form with islands or islets in it, the shallow rim enclosing a deeper central area or lagoon.

bay. An arm of the ocean, usually smaller than a gulf, that may vary greatly in size.

bayou. A minor sluggish waterway or estuarial creek, generally tidal or characterized by a slow or imperceptible current, and with its course generally through lowlands or swamps, tributary to or connecting other streams or bodies of water.

bight. A small open bay formed by an indentation in the coast, usually not more pronounced than a 90° segment of a circle.

brook, run, or branch. Minor streams usually tributary to creeks or rivers.

cape. A relatively extensive land area jutting seaward from a continent, or large island, which prominently marks a change in or interrupts notably the coastal trend; a large feature. Sometimes called a promontory or headland when its termination is particularly rugged or prominent.

cove. A small sheltered recess or indentation in a shore or coast, generally inside a larger embayment.

creek. A stream, less prominent than a river in any region, generally tributary to a river or another creek, but often flowing into a bay or ocean.

harbor. A natural or artificially improved body of water providing protection for vessels, and generally anchorage and docking facilities.

inlet. An arm of the sea, comparatively long with respect to its width and not restricted at its entrance, which may extend a a considerable distance inland; or a relatively narrow passage connecting a virtually enclosed body of water with the sea.

island. A land area, smaller than a continent, extending above and completely surrounded by water at mean high water.

islet. A very small and minor island.

key. A small low island, usually composed of sand and coral, spelled CAY in the British West Indies, and CAYO by the Spanish.

lagoon. A shallow body of salt or brackish water of varying size, near the shore and at or very close to sea level, communicating with the sea through a restricted outlet; a body of water enclosed by the reef of an atoll.

lake. Generally a body of fresh water well above sea level. There are exceptions such as the lakes in Louisiana which are open to or connect with the Gulf of Mexico; also sometimes applied to wide areas of a river.

middle ground. A shoal in a fairway having a channel on either side. Though a

specific name is seldom applied to this term, it is used very often on charts.

narrows. Usually the most restricted part of a passage between islands or between an island and the mainland.

neck. A term used in several ways, as (a) the equivalent of an isthmus, (b) a small peninsula, (c) the land areas between streams flowing into a sound or bay.

pass or passage. A waterway between islands, islands and the mainland, or between large groups of islands. A pass is usually a larger feature than a passage which is more comparable to a narrows.

point. The extreme end of a cape, or the outer end of any land area protruding into the water and smaller than a cape. The two terms are not interchangeable.

river. A stream of water larger than a creek flowing into another river, a lake, or the sea. In some areas the term river has been applied to streams no larger than brooks; conversely the term creek has been applied to streams which are ordinarily classified as rivers.

slough. A minor marshland or tidal waterway which usually connects other tidal areas; often more or less equivalent to a bayou; occasionally applied to the sea level portion of a creek on the West coast.

sound. A long passage of water connecting two larger bodies but too extensive to be termed a strait or pass. The term has been applied to many features which do not fit the accepted definition. Many are very large bodies of water, such as Mississippi Sound and Prince William Sound, others are mere salt water ponds or small passages between islands.

spit. A small tongue of land, usually low and narrow, extending into a body of water and generally continuing in a long narrow shoal for some distance from the shore.

strait. A passageway connecting two large bodies of water. The term is applied indiscriminately to waterways of all sizes both in length and width.

The terms pass, passage, strait, and narrows, are generally indicative of the same type of feature. The term "channel" has been used frequently in the name of such natural features, but is ordinarily limited to an improved waterway. As a general rule the terms passage and narrows are applied in speaking of features smaller than a pass or strait.

stream. Occasionally used in place of creek or brook especially in Maine and Hawaii.

thorofare. This shortened form of thoroughfare has become standard for a natural waterway in marshy areas. It is the same type of feature as a slough or bayou.

B. Submerged Features

bank. An elevation of the sea floor located on a continental shelf or an island shelf and over which the depth of water is relatively shallow but sufficient for safe surface navigation.

basin. A depression of the sea floor more or less equidimensional in form. When the length is much greater than the width, the feature is a trough.

canyon. A relatively narrow, deep valley with steep slopes, the bottom of which grades continually downward.

continental shelf. A zone adjacent to a continent and extending from the low waterline to the depth at which there is a marked increase of slope to greater depth.

continental slope. A declivity from the outer edge of a continental shelf or continental borderland into greater depths.

cordillera. An entire mountain province, including all the subordinate mountain ranges and groups and the interior plateaus and basins.

deep. A relatively small area of exceptional depth found in a depression. The term is generally restricted to depths greater than 3000 fathoms.

dome. A small elevation on a continental or island shelf with a characteristically rounded profile.

escarpment. An elongated and comparatively steep slope of the sea floor, separating flat or gently sloping areas.

fan. A gently sloping, cone-shaped accumulation of material normally located at the mouth of a submarine canyon.

island shelf. A zone adjacent to an island and extending from the low waterline to the depth at which there is a marked increase of slope to greater depth.

island slope. A declivity from the outer edge of an island shelf into greater depths.

knoll. A seamount rising less than 500 fathoms from the sea floor and having a pointed or rounded top.

peak. A seamount rising more than 500 fathoms from the sea floor and having a pointed or rounded top.

pinnacle. Any characteristic rocky column which is dangerous to surface navigation.

plain. A flat, gentle sloping or nearly level region of the sea floor.

plateau. A comparatively flat-topped elevation of the sea floor greater than 60 nautical miles across the summit and normally rising more than 100 fathoms on all sides.

province. A region composed of a group of similar bathymetric features whose characteristics are markedly in contrast with surrounding areas.

reef. Any coral elevation, or a detached rocky elevation that is dangerous to surface navigation and may uncover. A rocky reef is detached from shore but a coral reef may or may not extend from the shore.

ridge. A long, narrow elevation of the sea floor, with steep sides and more irregular topography than a rise.

rise. A long, broad elevation that rises gently and smoothly from the sea floor.

saddle. A low point on a ridge or between seamounts.

sea channel. A long, narrow, U-shaped or V-shaped shallow depression of the sea floor, usually occurring on a gently sloping plain or fan.

seamount. An elevation of the sea floor having a nearly equidimensional plan less than 60 nautical miles across the summit.

shelf edge. A line along which there is a marked increase of slope at the outer margin of a continental shelf or island shelf. For charting purposes the 100-fathom depth contour is nominally accepted as the shelf edge; the actual depth usually is less but may be more.

shoal. A detached non-coral or non-rocky area which is a menace to surface navigation and may change in shape or shift in position.

sill. A ridge or rise separating partially closed basins from one another or from the adjacent sea floor.

spur. A subordinate ridge or rise projecting outward from a larger feature of elevation.

terrace. A bench-like feature bordering an elevation of the sea floor. A terrace does not include the continental shelf or island shelf but may include bench-like features on the shelf.

trench. A long, narrow depression of the sea floor, having relatively steep sides.

trough. A long depression of the sea floor, having relatively gentle slopes, normally wider and shallower than a trench. To distinguish between trench and trough, it is useful to have a limiting characteristic such as total relief. It is suggested that a feature with a total relief of less than 500 fathoms be called a trough while one with greater total relief be called a Trench.

valley. A relatively shallow, wide depression with gentle slopes the bottom of which grades continuously downward. This term is used for features that do not have canyon proportions in any significant part of their extent.

7–18 **Reports on landmarks.**—The report on landmarks shall ordinarily consist of three parts: (a) landmarks to be charted; (b) charted landmarks to be deleted; (c) fixed aids to navigation.

The hydrographer shall examine the charts of the area to determine which charted landmarks are adequate for the purpose intended and to discover which charted landmarks no longer exist. If there are more conspicuous objects in the area which should be charted, their position shall be determined and listed as in (a) above.

Reports on landmarks shall, if possible, be complete in themselves in order that further reference to triangulation or photogram-

metry data may be avoided. The report shall state whether or not an inspection has been made to determine the value of the landmarks when viewed from the water area.

Flagstaffs and flagpoles because of their temporary nature should be listed as landmarks only where there are no other suitable objects in the vicinity or if they are of a very permanent nature.

7–19 Preparation of reports on landmarks.—When only a few objects are reported, Form 567 may be used. Where a number of landmarks are reported Form 567 shall be accompanied by sections of charts. The forms shall be prepared as follows:

(a) Objects of special importance or prominence shall be indicated by an asterisk (*) preceding the name of the object. In the selection of these the total area involved should be considered.

(b) In the first column headed "Charting Name" shall be shown in capital letters the name recommended for charting. It should be a short and general name as shown in 7–21. A short description shall be entered in the next column. If the object was used as a signal to control hydrography, the name used for this purpose shall be entered in the third column.

(c) In the columns headed "Position" the position, where accurately known, shall be given in degrees, minutes and the dms. and dps. in meters, and where so given the data will be considered accurate enough for charting purposes. The datum, method of location, and chart numbers of the charts affected shall be given. The data entered on the form must be verified and the form signed by the verifier.

(d) The form shall be forwarded in duplicate. The duplicate copy shall be marked "Coast Pilot Section" and notations made on it as to the relative prominence of each landmark and how the landmarks affect the Coast Pilot.

7–20 Preparation of chart-sections.—Where a number of landmarks are reported, a recently printed copy of the chart of the area, cut into letter size sections, shall be prepared in addition to Form 567. Only one copy of chart-sections need be submitted. The area which has been inspected shall be outlined on these chart sections and a recommendation shall be made for each charted or plotted landmark within the area outlined. The following procedure shall be used:

(a) New landmarks shall be plotted and identified by the landmark symbol (⊙) accompanied by the name recommended for charting. The geographic datum of the chart must be known and considered in the plotting.

(b) Charted landmarks, the continuance of which is recommended, shall be checkmarked (√), and where the position has actually been verified during field work, the checkmark shall be accompanied by the word "verified."

(c) Charted landmarks, the deletion of which is recommended, shall be indicated by an X in a circle, accompanied by the word "delete" (X delete) and the reason for the recommendation shall be given.

If chart sections are submitted, landmarks to be deleted need not be listed on Form 567.

Where new uncharted landmarks are shown on the chart submitted, a notation shall be made thereon in a prominent place giving the latitude and longitude, with seconds in meters, of some one charted landmark. The datum used shall be shown on the chart.

Names and notations on these chart sections shall be typed or lettered legibly in red ink. Care must be taken that such notations always appear on the same section as the landmarks to which they refer.

7–21 Standardization of nomenclature.—It is essential for charting purposes that the nomenclature used, and the method of reporting it, be standardized. The cartographers should not have to interpret these data because they cannot see the object in the field and cannot know what is most prominent about the landmark. If a landmark is reported on Form 567 as a "Tall yellow tank," the cartographer cannot tell whether the landmark is prominent because it is a tank, because it is yellow, or because it is

tall. The field party must interpret these data and give them in proper form for charting. The following standardization of nomenclature must be considered general but is to be followed so far as practicable.

In general, descriptive terms shall be omitted from the name recommended for the chart. Colors describing an object are particularly objectionable on account of their temporary nature. The material out of which an object is built is not valuable on the chart, since the mariner even where only a short distance away cannot identify an object by the material. The adjectives tall and tallest are unnecessary, because if the object were not tall it would not be a prominent landmark. Where a descriptive term is necessary to distinguish a charted landmark from other landmarks in the vicinity which are not charted or not located, then the descriptive term shall be in capital letters.

In general the use to which an object is put is nonessential on the chart, unless this use contributes to the identification of the object. In reporting buildings as landmarks, avoid so far as possible using a name that indicates the use to which the building is put. It is preferable to use some term such as DOME, TOWER, or SPIRE, which describes the shape of the top of the building. The name describing the use, such as schoolhouse or courthouse, shall follow in lowercase letters.

In general the company's name shall be omitted from the chart unless this name or an abbreviation of it is visible on the landmark in letters large enough to serve as an identifying feature to the mariner.

In a few cases of very well-known buildings, the name of the building shall be charted in parentheses following the name of the landmark, as DOME (STATE HOUSE), TOWER (EMPIRE STATE BLDG.).

Where two similar objects are closely adjacent the word "twin" shall be omitted if the objects are charted as two separate landmarks. Where they are indicated as only one landmark the word "twin" shall be used.

In cases where only one of a group is to be charted, the name should be followed in parentheses by a descriptive legend, including the number in the group, as for example (TALLEST OF FOUR) or (NORTHEAST OF THREE).

In the name or description of a landmark, its relation to other topographic features is unessential since this is shown graphically on the chart.

The following classifications, which include most landmarks, are defined and accompanied by remarks to standardize their use. They shall be so used so far as practicable.

building. (See house).

chimney. That projecting part of a building for conveying smoke, etc., to the outer air. This term is to be used only where the building is the prominent feature and the charting of some specific part of it is desirable; for example, the chimney of a large factory.

cupola. A small turret or dome-shaped tower rising from a building, in cases where the building is the prominent object and where the cupola is small as compared to the building.

dome. A large cupola or rounded hemispherical form, or a roof of the same shape, whether it is actually rounded or many-sided.

flagpole. A single staff flagpole rising from the ground and not attached to a building.

flagstaff. A single staff flagpole rising from a building. This is not desirable as a landmark, due to its nonpermanence. Although it is desirable that the most definite part of a building (such as the flagstaff) be pointed at in making observations, this is not necessarily the most important part for charting purposes. Wherever possible give, for use on the chart, that part of the building from which the flagstaff rises, as TOWER, CUPOLA, DOME, etc.

flag tower. Any scaffold-like tower on which flags are hoisted, such as a Coast Guard skeleton steel flagpole or a Weather Bureau signal tower. Do *not* use *Signal Tower.*

gas tank or oil tank. Since these differ

in shape and size from a water tank, the compound name will be used.

house or building. Although it is desirable to locate a house or building by observations on a specific point, as the west gable or the flagstaff, such terms are not desirable for charting purposes, where it is the structure itself which is the landmark. Use HOUSE or BUILDING followed by a description of the point in either capitals or lower-case letters, according to whether it should be used on the chart or not. Where the outline of the building should be shown on the chart, the following notation—"chart outline"—should be made on Form 567.

lookout tower. Any tower surmounted by a small house in which a watch is habitually kept, such as a Coast Guard lookout tower or a fire lookout tower. Do *not* use this term in describing an observation tower, or a part of a building in which no watch is kept.

monument. Do *not* use *Obelisk* or other terms.

radar tower. A tower or structure used to elevate parobolic or mattress type radar reflectors.

radio mast. A general term to include any tower, pole or structure for elevating antennas.

spire. In general, any slender pointed structure surmounting a building. Do *not* use *Steeple.* Spire is not applicable to a short pyramid-shaped structure rising from a tower or belfry.

stack. Any tall smokestack or chimney, regardless of color, shape, or material, if the stack is more prominent, as a landmark, than any buildings in connection with it. Do *not* use *Chimney.*

standpipe. A tall cylindrical structure, in a waterworks system, whose height is several times greater than its diameter.

tank. A tank for holding water, when its base rests on the ground or other foundation, and its height is not much greater than its diameter.

tank (elevated). A tank for holding water, where such tank is elevated high above the ground or other foundation by a tall skeleton framework.

television tower. A tall slender structure for elevating antennas.

tower. (a) A part of a structure higher than the rest, but having vertical sides for the greater part of its height.

(b) An isolated structure with vertical sides (not otherwise classified), high in proportion to the size of its base, and of simple form.

(c) The top of a skyscraper, high in proportion to its horizontal size and rising above its surroundings.

(d) Any structure, whether its sides are vertical or not, with base on the ground and high in proportion to its base.

tree. Do *not* use *Lone tree* or *Conspicuous lone tree.* This is assumed, otherwise the tree would not serve as a landmark.

water tower (infrequent). A decorative structure enclosing a tank or standpipe, or used as such, when by its appearance it would not be recognized as such.

windmill. A self-explanatory term.

Examples

CHIMNEY, schoolhouse (Mt. Vernon H.S.)

CUPOLA, schoolhouse (Normal School, 98 ft. high)

FLAGPOLE (Green Hill Country Club)

LOOKOUT TOWER, fire, steel (110 ft. high)

SPIRE, church (△ Nanticoke Church Spire)

STACK (Aiea Mill)

STACK, black, metal (at Hot House)

STACK (TALLEST OF FOUR), black

STACK, white, concrete

TANK (BAY STATE STATE CO) (⊙ Bay)

TANK (SOUTH) (southerly of three yellow tanks)

*TANK, steel (125 ft. high)

TANK, yellow (△ Hot)

*TOWER (CITY HALL)

7–22 Report on fixed aids to navigation. —Form 567, Landmarks for Charts, is also

used to report the positions of fixed aids to navigation in the project area (see 5–80). The positions of all fixed aids must be determined or verified, including all privately maintained lights and beacons. Applicable parts of the instructions contained in 7–18 and 19 should be followed in compiling this report. It is important that the names of the aids entered on the form be identical with those in the Light List, and the Light List number should be given. The position of each aid should be plotted on the largest scale chart of the area and compared with the charted position. Significant differences should be reported to the Coast Guard District Headquarters and the Washington Office.

The report shall be made on an area or seasonal basis. A separate report for each hydrographic sheet is not desired. The aids to navigation shall be listed separately from the landmarks, since these reports serve a different purpose in the office.

7–23 Reports on dangers to navigation.—All shoals, obstructions, wrecks, or other submerged features discovered that are considered dangers to navigation shall be reported immediately by radio, telephone, or telegraph to the Commander of the nearest United States Coast Guard District and to the Coast and Geodetic Survey District Office (see 1–51). The message shall be in the following form: "(object) covered by (depth of water) at (datum) discovered; distant ___ nautical miles or yards, bearing ___ degrees true from (charted object)."

A tracing from the boat sheet or chart showing the exact location of the danger discovered should be forwarded to the Washington Office at the earliest opportunity. A statement shall be included in the descriptive report mentioning each danger reported to the Coast Guard, (7–4K), so that such information will not be duplicated.

Floating wreckage, logs, derelicts, or other floating objects sighted which are menaces to navigation shall be promptly reported by dispatch to the Commander of the nearest Coast Guard District.

When a floating aid to navigation is found to be off station to an extent that it does not adequately serve its purpose and may create a danger to navigation, the facts should be reported to the nearest Coast Guard District by dispatch (see 1–50).

The necessity for prompt action in all the above situations cannot be overemphasized. Dispatches should always be confirmed in writing. Copies of all correspondence with the Coast Guard shall be forwarded to the Washington Office.

7–24 Shipment of records.—Field records should be processed in an orderly manner as time and circumstances permit. Completed records should be forwarded to the Washington Office promptly. When photogrammetric manuscripts must be recompiled or revised prior to application to a smooth sheet, all photographs and supporting data should be transferred to the designated photogrammetric office as soon as possible after field work has been completed for each sheet or small group of sheets. Retention of these data until the end of the season will cause delays in further processing.

The Chief of Party should inspect all records and reports to see that they are complete. Any deficiency must be fully explained.

Form 413, Letter Transmitting Data, shall be used when transmitting records to any office or field party. The original and one copy of the form shall be forwarded to the addressee in a separate envelope. One copy of the form shall be enclosed with each package of a shipment. Each package of a season's work shall be numbered consecutively, beginning with No. 1 and continuing until all data for the season have been forwarded.

All records shall be well wrapped or boxed and forwarded by registered mail or express. Smooth sheets shall be transmitted in special non-breakable containers furnished for that purpose. The smooth sheet, boat sheet, sounding records, and fathograms shall be forwarded in separate mails as security against total loss of the survey records. The general rule is that computations or other processed data shall not be forwarded with the original records.

Records and computations destined to dif-

ferent divisions should not be combined in one transmitting letter.

7–25 Data to be forwarded.—For convenient reference there is given herewith a summary of the data to be forwarded to the Washington Office in connection with different types of hydrographic surveys. This list should be consulted before the records and reports are prepared for shipment.

A. For every hydrographic survey.

Smooth sheet:
- Copy of hydrographic title sheet (Form 537).
- Blue line tracings of shoreline manuscripts.

Boat sheet:
- Overlays (when applicable).

Sounding records.

Fathograms.

Descriptive Report:
- Hydrographic title sheet.
- Processing Office addendum (when applicable).
- Overlay tracings of congested areas.
- List of control stations.
- Abstract of corrections to electronic distance measurements (when applicable).
- Tide note.
- Abstract of echo sounding corrections.
- Geographic name list.
- Approval sheet.

Photogrammetric manuscripts.

Descriptions of topographic stations (Form 524).

Recovery notes for topographic stations (Form 524).

B. Season or Area Reports.

Echo sounding correction reports.

Calibration of electronic control systems (when used).

Temperature and salinity observations.

Landmarks for charts (Form 567).

Positions of fixed aids to navigation (Form 567).

Coast Pilot notes.

Geographic name report.

Season's progress sketch.

Triangulation progress sketch.

Triangulation station descriptions (Form 525).

Triangulation station recovery notes (Form 526).

Current observations.

Magnetic observations.

Bathythermograph slides and log sheets.

Tide station reports and leveling records.

Marigrams.

7–26 Report on corrections to echo soundings.—A report on corrections to echo soundings shall be submitted at the conclusion of a field season or hydrographic survey project. The method used to determine the corrections shall be stated but need not be described in detail except when an unusual method is employed. The mean regional temperature and salinity curves for each area or period of time and the computations of velocity corrections shall be included with this report. The record of observed temperatures and salinities should be bound and forwarded separately.

The abstracts of bar checks, vertical cast comparisons, and phase comparisons should be included with the report. Tables of corrections should identify the soundings to which they apply and a copy of the applicable tables shall be included in the descriptive report to accompany each smooth sheet.

The report should include all basic data adequately referenced and tabulated, including graphs, so that calibrations can be readily verified. When the report covers several project surveys, or when various vessels and echo sounders were used on the survey, a chronological tabulation should be included which references ships, launches, and echo sounders common to the surveys during the operating season. This will facilitate tracing basic information involved in correction factors.

When a velocimeter is used in the determination of velocity corrections, the instrument should be identified by number and the date of the most recent calibration should be stated.

When an EDO–255 echo sounder is operated at any frequency other than the standard 60 cycles, conforming to a calibrated velocity of 800 fathoms (4,800 feet) per

second, the report shall state the frequency, or frequencies, used; the areas where each non-standard frequency was used; and the method employed to determine appropriate frequencies.

Verification of hydrographic smooth sheets occasionally reveals inconsistencies in hydrography which are caused by improper use of available correction data. The results of successive bar checks should not be averaged when they differ appreciably (see 5–115). When the phasing head on 808 Fathometers is not shifted correctly, phasing errors change. Results of inconsistent phase comparisons should not be averaged.

7–27 Electronic systems calibration reports.—When an electronic distance measuring system is used to control hydrographic surveys, a report on calibration of the system and summary of corrections to distance measurements shall be submitted at the end of a project or field season. The methods used to calibrate the equipment should be described briefly; unusual methods should be described in detail and the necessity for using non-standard methods should be stated.

Requirements for calibration of EPI equipment are stated in 3–29. The results of tests to determine the effect of the ship's heading should be tabulated (see 3–30).

Calibration of Shoran equipment is discussed in 3–38 to 42. It is important that a continuous study of Shoran corrections be conducted during progress of the survey. The final report should contain an analysis of the calibrations. The geographic coordinates of all calibration points should be listed and the dates when calibrations were made at each point should be given (see 3–46).

Tables of distance corrections should be included and properly referenced to date and survey ship or launch. Computations of position data and similar material should not be included in the report.

Difficulties in operation of the equipment, other than routine maintenance problems, should be described.

Corrections to Raydist measurements are described in 3–56 and procedures for calibrating the equipment are described in 3–58 to 60. A report on calibration of Raydist equipment shall be submitted at the end of a field season or on completion of a project. The report shall summarize the procedures used and the results obtained.

When any survey is plotted by boat-smooth sheet methods and an electronic distance measuring system is used for control, the report on calibrations shall include a statement regarding the adequacy of the preliminary calibration data used to correct observed distances.

7–28 Velocity of sound computations.—If the temperature and salinity of sea water at a specific depth are known, the velocity of sound at that depth may be derived from Tables 14, 15, and 16. These tables are based on Tables of the Velocity of Sound in Pure Water and Sea Water, H.D. 282, published by the Hydrographic Department of the British Admiralty. In Table 14 are given the velocities (in meters per second) for various temperatures at surface atmospheric pressure and at an assumed salinity of 35.0 $^0/_{00}$. The correction to be applied for any other salinity is given in Table 15; it is subtractive for salinities less than 35.0 $^0/_{00}$ and additive for salinities above 35.0 $^0/_{00}$. The correction for pressure at latitude 45° is given in Table 16; it is always additive. The pressure correction varies not only with hydrostatic pressure, but also with gravity and therefore slightly with latitude; but the mean values in Table 16 are sufficiently accurate for all surveying purposes. The pressure correction is nearly proportional to depth, and for depths less than 1,000 fathoms, it may be found with sufficient accuracy by dividing the depth (in fathoms) by 30—the result being the correction in meters per second.

7–29 Velocity from diagrams.—The diagrams (Figs. 87 and 88) may be used instead of the tables in 7–28 to find velocities. These diagrams are based on the values in the tables but, owing to their small scale, the velocities cannot be derived with quite the accuracy that the tables will give. But if the values are interpolated carefully from the diagrams the resulting velocities should

TABLE 14.—Velocity of sound in sea water—in meters per second, at surface atmospheric pressure and salinity 35 °/₀₀.

[Enter this table with the temperature. Apply a correction for salinity from table 15, and a correction for pressure from table 16.]

Temp. °C.	0	.1	.2	.3	.4	.5	.6	.7	.8	.9
−1	1440.8	40.3	39.9	39.4	38.9	38.5	38.0	37.5	37.1	36.6
−0	1445.4	45.0	44.5	44.0	43.6	43.1	42.7	42.2	41.7	41.3
0	1445.4	45.9	46.3	46.8	47.3	47.7	48.2	48.6	49.1	49.5
1	1450.0	50.4	50.9	51.3	51.8	52.2	52.7	53.1	53.5	54.0
2	1454.4	54.9	55.3	55.7	56.2	56.6	57.1	57.5	57.9	58.4
3	1458.8	59.2	59.6	60.1	60.5	60.9	61.4	61.8	62.2	62.6
4	1463.1	63.5	63.9	64.3	64.7	65.2	65.6	66.0	66.4	66.8
5	1467.2	67.6	68.0	68.4	68.8	69.3	69.7	70.1	70.5	70.9
6	1471.3	71.7	72.1	72.5	72.9	73.3	73.7	74.1	74.5	74.9
7	1475.3	75.7	76.1	76.5	76.9	77.3	77.6	78.0	78.4	78.8
8	1479.2	79.6	80.0	80.3	80.7	81.1	81.5	81.9	82.2	82.6
9	1483.0	83.4	83.7	84.1	84.5	84.8	85.2	85.6	86.0	86.3
10	1486.7	87.1	87.4	87.8	88.1	88.5	88.9	89.2	89.6	89.9
11	1490.3	90.7	91.0	91.4	91.7	92.1	92.4	92.8	93.1	93.5
12	1493.8	94.2	94.5	94.8	95.2	95.5	95.9	96.2	96.6	96.9
13	1497.2	97.6	97.9	98.2	98.6	98.9	99.2	99.6	99.9	1500.2
14	1500.6	00.9	01.2	01.5	01.9	02.2	02.5	02.8	03.2	03.5
15	1503.8	04.1	04.4	04.7	05.1	05.4	05.7	06.0	06.3	06.6
16	1506.9	07.2	07.6	07.9	08.2	08.5	08.8	09.1	09.4	09.7
17	1510.0	10.3	10.6	10.9	11.2	11.5	11.8	12.1	12.4	12.7
18	1513.0	13.3	13.6	13.9	14.1	14.4	14.7	15.0	15.3	15.6
19	1515.9	16.2	16.4	16.7	17.0	17.3	17.6	17.9	18.1	18.4
20	1518.7	19.0	19.2	19.5	19.8	20.1	20.3	20.6	20.9	21.2
21	1521.4	21.7	22.0	22.2	22.5	22.8	23.0	23.3	23.6	23.8
22	1524.1	24.4	24.6	24.9	25.2	25.4	25.7	25.9	26.2	26.4
23	1526.7	27.0	27.2	27.5	27.7	28.0	28.2	28.5	28.7	29.0
24	1529.2	29.5	29.7	30.0	30.2	30.5	30.7	31.0	31.2	31.5
25	1531.7	31.9	32.2	32.4	32.7	32.9	33.1	33.4	33.6	33.9
26	1534.1	34.3	34.6	34.8	35.0	35.3	35.5	35.7	36.0	36.2
27	1536.4	36.7	36.9	37.1	37.4	37.6	37.8	38.0	38.3	38.5
28	1538.7	38.9	39.2	39.4	39.6	39.8	40.0	40.3	40.5	40.7
29	1540.9	41.1	41.4	41.6	41.8	42.0	42.2	42.4	42.7	42.9

TABLE 15.—Salinity corrections.—Corrections in meters per second, to be applied to the velocities in table 14 to account for salinity

[Enter this table with the salinity and temperature of water in °C. at the depth. When the salinity is more than 35 °/₀₀ the correction is additive; when less, it is subtractive.]

Salinity °/₀₀	Temperature °C. at depth						
	0	5	10	15	20	25	30
0	−46.1	−44.4	−42.4	−40.6	−39.2	−38.5	−38.8
5.0	−39.5	−38.1	−36.4	−34.8	−33.6	−32.9	−33.0
10.0	−32.8	−31.7	−30.3	−29.0	−27.9	−27.2	−27.2
15.0	−26.2	−25.4	−24.2	−23.2	−22.2	−21.6	−21.5
20.0	−19.6	−19.0	−18.2	−17.4	−16.6	−16.0	−15.7
21.0	−18.3	−17.7	−17.0	−16.3	−15.5	−15.0	−14.7
22.0	−17.0	−16.4	−15.8	−15.2	−14.4	−13.9	−13.6
23.0	−15.7	−15.2	−14.5	−14.0	−13.3	−12.8	−12.6
24.0	−14.3	−13.9	−13.3	−12.8	−12.2	−11.8	−11.5
25.0	−13.0	−12.6	−12.1	−11.6	−11.1	−10.7	−10.5
26.0	−11.7	−11.4	−10.9	−10.5	−10.0	−9.6	−9.4
27.0	−10.4	−10.1	−9.7	−9.3	−8.9	−8.5	−8.4
28.0	−9.1	−8.8	−8.5	−8.1	−7.8	−7.4	−7.4

TABLE 15.—Salinity corrections.—Continued

Salinity °/oo	Temperature °C. at depth						
	0	5	10	15	20	25	30
29.0	−7.8	−7.6	−7.3	−7.0	−6.7	−6.4	−6.3
30.0	−6.5	−6.4	−6.1	−5.8	−5.5	−5.4	−5.2
30.2	−6.2	−6.1	−5.8	−5.6	−5.3	−5.1	−5.0
30.4	−6.0	−5.8	−5.6	−5.3	−5.1	−4.9	−4.8
30.6	−5.7	−5.6	−5.3	−5.1	−4.8	−4.7	−4.6
30.8	−5.5	−5.3	−5.1	−4.9	−4.6	−4.5	−4.4
31.0	−5.2	−5.0	−4.8	−4.6	−4.4	−4.3	−4.2
31.2	−4.9	−4.8	−4.6	−4.4	−4.2	−4.1	−4.0
31.4	−4.7	−4.6	−4.3	−4.2	−4.0	−3.9	−3.8
31.6	−4.4	−4.3	−4.1	−4.0	−3.7	−3.6	−3.5
31.8	−4.2	−4.0	−3.8	−3.7	−3.5	−3.4	−3.3
32.0	−3.9	−3.8	−3.6	−3.5	−3.3	−3.2	−3.1
32.2	−3.6	−3.5	−3.4	−3.3	−3.1	−3.0	−2.9
32.4	−3.4	−3.3	−3.1	−3.0	−2.9	−2.8	−2.7
32.6	−3.1	−3.0	−2.9	−2.8	−2.6	−2.6	−2.5
32.8	−2.9	−2.8	−2.6	−2.5	−2.4	−2.4	−2.3
33.0	−2.6	−2.5	−2.4	−2.3	−2.2	−2.2	−2.1
33.2	−2.3	−2.2	−2.2	−2.1	−2.0	−2.0	−1.9
33.4	−2.1	−2.0	−1.9	−1.8	−1.8	−1.8	−1.7
33.6	−1.8	−1.7	−1.7	−1.6	−1.5	−1.5	−1.4
33.8	−1.6	−1.5	−1.4	−1.4	−1.3	−1.3	−1.2
34.0	−1.3	−1.2	−1.2	−1.2	−1.1	−1.1	−1.0
34.2	−1.0	−1.0	−1.0	−1.0	−0.9	−0.9	−0.8
34.4	−0.8	−0.7	−0.7	−0.7	−0.7	−0.7	−0.6
34.6	−0.5	−0.5	−0.5	−0.4	−0.4	−0.4	−0.4
34.8	−0.3	−0.2	−0.2	−0.2	−0.2	−0.2	−0.2
35.0	0	0	0	0	0	0	0
35.2	0.3	0.3	0.2	0.2	0.2	0.2	0.2
35.4	0.6	0.5	0.5	0.4	0.4	0.4	0.4
35.6	0.8	0.8	0.7	0.7	0.7	0.6	0.6
35.8	1.1	1.0	1.0	0.9	0.9	0.8	0.8
36.0	1.4	1.3	1.2	1.1	1.1	1.0	1.0
36.2	1.7	1.6	1.4	1.3	1.3	1.2	1.2
36.4	1.9	1.8	1.7	1.6	1.5	1.4	1.4
36.6	2.2	2.0	1.9	1.8	1.8	1.7	1.6
36.8	2.4	2.3	2.2	2.1	2.0	1.9	1.8
37.0	2.7	2.6	2.4	2.3	2.2	2.1	2.0
37.2	3.0	2.8	2.6	2.5	2.4	2.3	2.2
37.4	3.2	3.0	2.9	2.8	2.6	2.5	2.4
37.6	3.5	3.3	3.1	3.0	2.9	2.8	2.7
37.8	3.7	3.6	3.4	3.2	3.1	3.0	2.9
38.0	4.0	3.8	3.6	3.4	3.3	3.2	3.1
38.2	4.3	4.0	3.9	3.6	3.5	3.4	3.3
38.4	4.6	4.3	4.1	3.9	3.7	3.6	3.5
38.6	4.9	4.6	4.4	4.2	4.0	3.8	3.7
38.8	5.1	4.8	4.6	4.4	4.2	4.0	3.9
39.0	5.4	5.1	4.9	4.6	4.4	4.2	4.1
40.0	6.7	6.3	6.0	5.7	5.5	5.2	5.1
41.0	8.1	7.6	7.0	6.8	6.5	6.4	6.1

TABLE 16.—Pressure corrections.—Corrections in meters per second, to be applied to the velocities in table 14 to account for the pressure or depth

[Enter this table with the depth in fathoms and the temperature of water in °C. at the depth. Add this correction to the velocities in table 14.]

Depths in fathoms	Temperature °C. at depth				
	−2	5	10	15	20
0	0	0	0	0	0
50	1.6	1.6	1.6	1.6	1.6
100	3.3	3.3	3.3	3.3	3.3
150	5.0	5.0	4.9	4.9	4.9
200	6.7	6.7	6.6	6.6	6.6
250	8.3	8.3	8.2	8.2	8.2
300	10.0	10.0	9.9	9.9	9.9
350	11.6	11.6	11.5	11.5	11.5
400	13.3	13.3	13.2	13.2	13.2
450	15.0	15.0	14.9	14.8	14.8
500	16.7	16.7	16.6	16.5	16.5
550	18.3	18.3	18.2	18.1	18.1
600	20.0	20.0	19.9	19.8	19.8
650	21.6	21.6	21.5	21.4	21.5
700	23.2	23.2	23.1	23.0	23.1
750	24.9	24.9	24.8	24.7	24.7
800	26.5	26.5	26.4	26.3	26.3
850	28.2	28.2	28.1	28.0	27.9
900	29.9	29.8	29.7	29.6	29.5
950	31.6	31.5	31.4	31.2	31.2
1,000	33.2	33.1	33.0	32.8	32.8

TABLE 16.—Pressure corrections.—Continued

Depths in fathoms	Temperature °C. at depth					
	0	1	2	3	4	5
1,000	....	....	....	....	....	33.1
1,050	34.9	34.9	34.9	34.9	34.9	34.8
1,100	36.5	36.5	36.5	36.5	36.5	36.4
1,150	38.2	38.2	38.2	38.2	38.2	38.2
1,200	39.8	39.8	39.8	39.8	39.8	39.8
1,250	41.5	41.5	41.5	41.5	41.5	41.5
1,300	43.2	43.2	43.1	43.1	43.1	43.1
1,350	44.8	44.8	44.8	44.7	44.7	44.7
1,400	46.5	46.5	46.5	46.4	46.4	46.3
1,450	48.1	48.1	48.1	48.0	48.0	47.9
1,500	49.8	49.8	49.8	49.7	49.7	49.6
1,550	51.4	51.4	51.4	51.3	51.3	51.2
1,600	53.1	53.1	53.1	53.0	53.0	52.9
1,650	54.7	54.7	54.7	54.6	54.6	54.5
1,700	56.4	56.4	56.4	56.3	56.3	56.2
1,750	58.0	58.0	58.0	57.9	57.9	57.8
1,800	59.7	59.7	59.6	59.6	59.5	59.4
1.850	61.3	61.3	61.2	61.2	61.1	61.0
1,900	62.9	62.9	62.8	62.8	62.7	62.6
1,950	64.6	64.6	64.5	64.4	64.4	64.3
2,000	66.2	66.2	66.1	66.0	66.0	65.9
2,100	69.5	69.4	69.4	69.3	69.2	
2,200	72.8	72.7	72.7	72.6	72.5	
2,300	76.1	76.0	75.9	75.8	75.7	

TABLE 16.—Pressure corrections.—Continued

Depths in fathoms	Temperature °C. at depth					
	0	1	2	3	4	5
2,400	79.3	79.2	79.2	79.1	79.0	
2,500	82.5	82.4	82.4	82.3	82.1	
2,600	85.8	85.7	85.7	85.6	85.4	
2,700	89.1	89.0	88.9	88.8	88.7	
2,800	92.3	92.2	92.1	92.0	91.9	
2,900	95.6	95.5	95.4	95.3	95.1	
3,000	98.9	98.7	98.6	98.5	98.3	
3,100	102.1	101.9	101.8	101.6	101.4	
3,200	105.3	105.2	105.0	104.8	104.6	
3,300	108.5	108.4	108.2	108.0	107.8	
3,400	111.7	111.6	111.3	111.1	110.9	
3,500	114.9	114.7	114.5	114.3	114.0	
3,600	118.1	117.9	117.7	117.4	117.2	
3,700	121.3	121.1	120.8	120.6	120.3	
3,800	124.5	124.3	124.0	123.8	123.5	
3,900	127.7	127.5	127.2	127.0	126.7	
4,000	130.9	130.6	130.3	130.1	129.8	

TABLE 17.—Velocity correction factors

Actual velocity (*in meters per second*)	Calibration velocity (*in fathoms per second*)		
	800	810	820
1,460	−0.00205	−0.01438	−0.02641
61	−0.00137	−0.01370	−0.02574
62	−0.00068	−0.01303	−0.02507
63	0.00000	−0.01235	−0.02441
64	+0.00068	−0.01168	−0.02374
65	+0.00137	−0.01100	−0.02307
66	+0.00205	−0.01033	−0.02241
67	+0.00273	−0.00965	−0.02174
68	+0.00342	−0.00898	−0.02107
69	+0.00410	−0.00830	−0.02041
1,470	+0.00478	−0.00763	−0.01974
71	+0.00547	−0.00695	−0.01907
72	+0.00615	−0.00628	−0.01840
73	+0.00684	−0.00560	−0.01774
74	+0.00752	−0.00493	−0.01707
75	+0.00820	−0.00425	−0.01640
76	+0.00889	−0.00358	−0.01574
77	+0.00957	−0.00290	−0.01507
78	+0.01025	−0.00223	−0.01440
79	+0.01094	−0.00155	−0.01374
1,480	+0.01162	−0.00088	−0.01307
81	+0.01230	−0.00020	−0.01240
82	+0.01299	+0.00047	−0.01174
83	+0.01367	+0.00115	−0.01107
84	+0.01435	+0.00182	−0.01040
85	+0.01504	+0.00250	−0.00974
86	+0.01572	+0.00317	−0.00907
87	+0.01640	+0.00385	−0.00840
88	+0.01709	+0.00452	−0.00774

TABLE 17.—Velocity correction factors—Continued

Actual velocity (in meters per second)	Calibration velocity (in fathoms per second)		
	800	810	820
89	+0.01777	+0.00520	−0.00707
1,490	+0.01846	+0.00587	−0.00640
1,491	+0.01914	+0.00655	−0.00573
92	+0.01982	+0.00722	−0.00507
93	+0.02051	+0.00790	−0.00440
94	+0.02119	+0.00857	−0.00373
95	+0.02187	+0.00925	−0.00307
96	+0.02256	+0.00992	−0.00240
97	+0.02324	+0.01060	−0.00173
98	+0.02392	+0.01127	−0.00107
99	+0.02461	+0.01195	−0.00040
1,500	+0.02529	+0.01262	+0.00027
01	+0.02597	+0.01330	+0.00093
02	+0.02666	+0.01397	+0.00160
03	+0.02734	+0.01465	+0.00227
04	+0.02802	+0.01532	+0.00293
05	+0.02871	+0.01600	+0.00360
06	+0.02939	+0.01667	+0.00427
07	+0.03008	+0.01735	+0.00493
08	+0.03076	+0.01802	+0.00560
09	+0.03144	+0.01870	+0.00627
1,510	+0.03213	+0.01937	+0.00694
11	+0.03281	+0.02005	+0.00760
12	+0.03349	+0.02073	+0.00827
13	+0.03418	+0.02140	+0.00894
14	+0.03486	+0.02208	+0.00960
15	+0.03554	+0.02275	+0.01027
16	+0.03623	+0.02342	+0.01094
17	+0.03691	+0.02410	+0.01160
18	+0.03759	+0.02478	+0.01227
19	+0.03828	+0.02545	+0.01294
1,520	+0.03896	+0.02613	+0.01360
21	+0.03964	+0.02680	+0.01427
22	+0.04033	+0.02748	+0.01494
23	+0.04101	+0.02815	+0.01560
24	+0.04170	+0.02883	+0.01627
25	+0.04238	+0.02950	+0.01694
26	+0.04306	+0.03018	+0.01760
27	+0.04375	+0.03085	+0.01827
28	+0.04443	+0.03153	+0.01894
29	+0.04511	+0.03220	+0.01961
1,530	+0.04580	+0.03288	+0.02027
31	+0.04648	+0.03355	+0.02094
32	+0.04716	+0.03423	+0.02161
33	+0.04785	+0.03490	+0.02227
34	+0.04853	+0.03558	+0.02294
35	+0.04921	+0.03625	+0.02361
36	+0.04990	+0.03693	+0.02427
37	+0.05058	+0.03760	+0.02494
38	0.05126	+0.03828	+0.02561
39	+0.05195	+0.03895	+0.02627
1,540	+0.05263	+0.03963	+0.02694

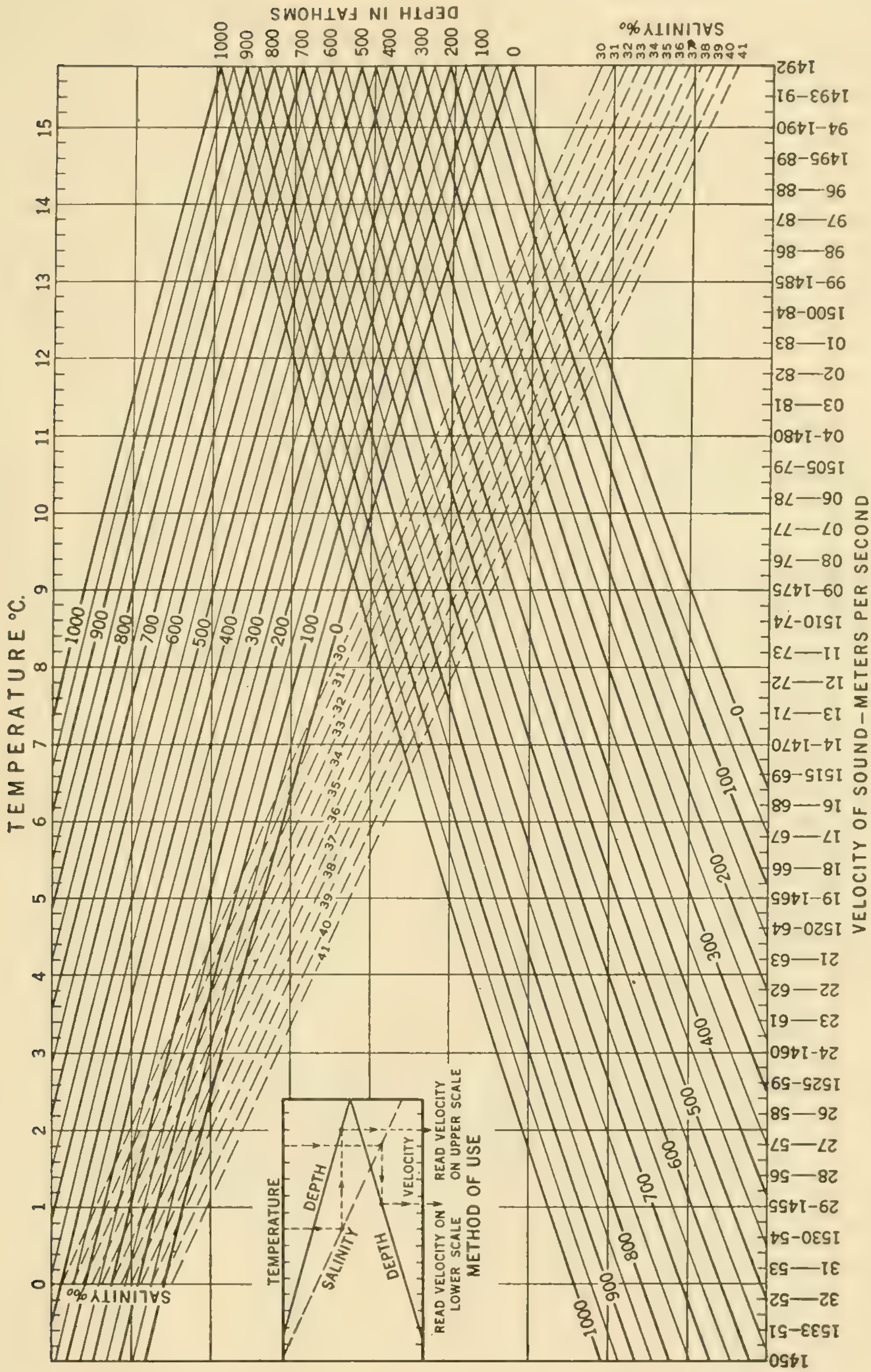


FIGURE 87.—Nomograph for derivation of velocity of sound in sea water (for temperatures from 0° to 15° centigrade).

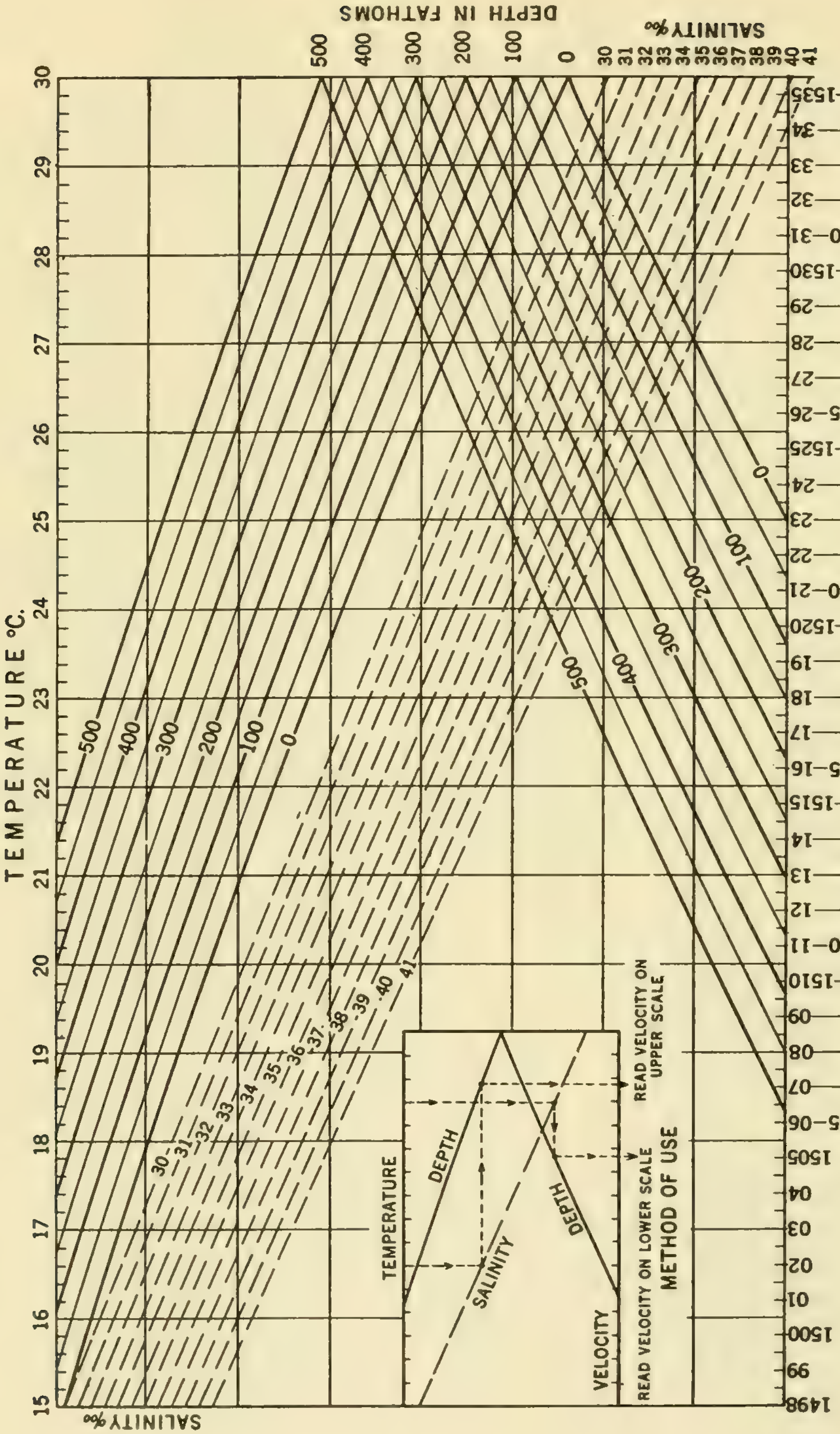


FIGURE 88.—Nomograph for derivation of velocity of sound in sea water (for temperatures from 15° to 30° centigrade).

be sufficiently accurate for use in computing echo-sounding corrections.

One diagram is for velocities for the range of temperatures from 0° to 15° C. and the other is for the range of temperatures from 15° to 30° C. Both diagrams are used in the same way. Enter the diagram with the temperature at depth on the scale at the top of the diagram and drop vertically to the diagonal line representing the salinity, then follow horizontally to the diagonal line representing the depth of the observation, and from here drop vertically to the abscissa scale at the bottom of the diagram and read the velocity of sound. If the upper series of depth curves is used the upper of the two velocity scales should be used, but if the lower series of depth curves is used the velocity should be read from the lower of the two velocity scales.

7–30 Standard widths of lines.—Standard widths of lines are shown in Figure 89 by reference to which the draftsman can gage the width prescribed for use in any given class of drafting. A linescope should be used when available.

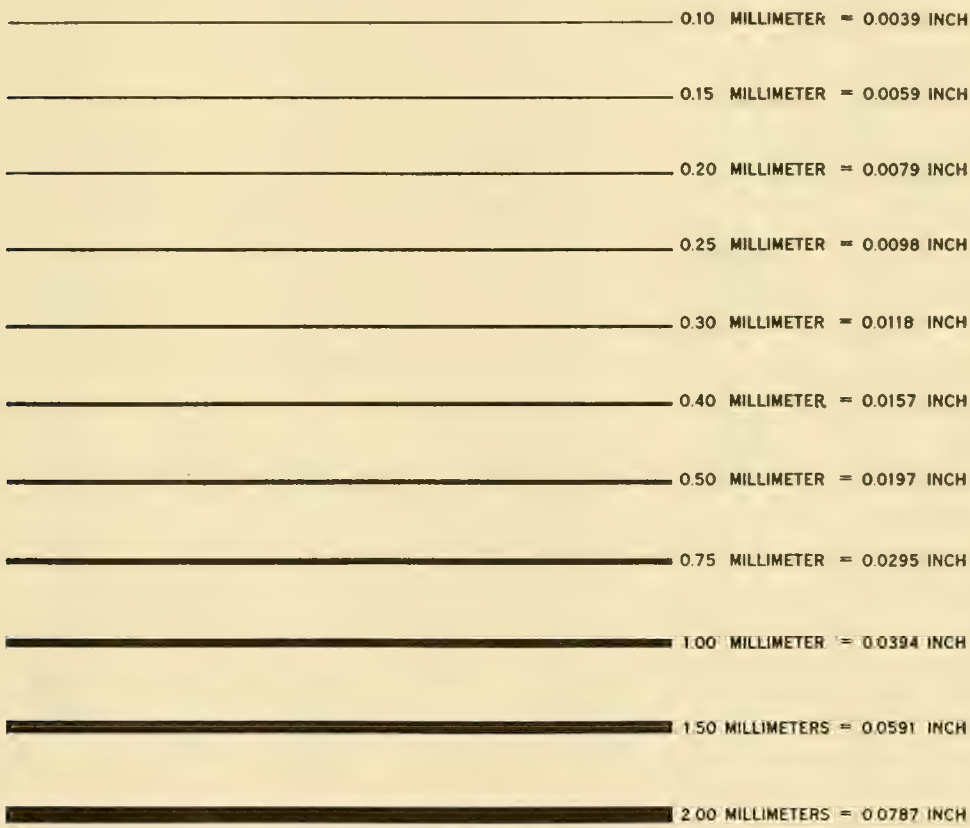


FIGURE 89.—Standard widths of lines.

7–31 Trigonometric functions for circle-sheet construction.—For use in constructing *circle sheets* (see 5–31) a table of natural half-cosecants and half-cotangents to four places is given. The values are given for each 10 minutes from 1° to 20°, for each half-degree from 20° to 50° and for each degree from 50° to 90°.

TABLE 18.—Natural half-cosecants and half-cotangents

Angle	½ cosec	½ cot	Angle	½ cosec	½ cot	Angle	½ cosec	½ cot
° ′			°			° ′		
1 00	28.6493	28.6450	8 00	3.5926	3.5577	15 00	1.9319	1.8660
10	24.5570	24.5519	10	.5198	.4841	10	.9111	.8445
20	21.4879	21.4820	20	.4499	.4135	20	.8908	.8235
30	19.1008	19.0942	30	.3827	.3456	30	.8710	.8029
40	17.1912	17.1839	40	.3182	.2803	40	.8516	.7828
50	15.6288	15.6208	50	.2560	.2174	50	.8326	.7630
2 00	14.3269	14.3181	9 00	3.1962	3.1569	16 00	1.8140	1.7437
10	13.2253	13.2158	10	.1386	.0985	10	.7958	.7248
20	12.2811	12.2709	20	.0830	.0422	20	.7779	.7062
30	11.4628	11.4519	30	.0294	2.9879	30	.7605	.6880
40	10.7468	10.7352	40	2.9777	.9354	40	.7434	.6701
50	10.1151	10.1028	50	.9277	.8847	50	.7266	.6526
3 00	9.5537	9.5406	10 00	2.8794	2.8356	17 00	1.7102	1.6354
10	9.0513	9.0375	10	.8327	.7882	10	.6940	.6186
20	8.5992	8.5847	20	.7875	.7423	20	.6782	.6020
30	8.1902	8.1749	30	.7437	.6978	30	.6628	.5858
40	7.8184	7.8024	40	.7013	.6546	40	.6476	.5699
50	7.4789	7.4622	50	.6602	.6128	50	.6327	.5542
4 00	7.1678	7.1503	11 00	2.6204	2.5723	18 00	1.6180	1.5388
10	6.8816	6.8634	10	.5818	.5329	10	.6037	.5237
20	.6174	.5984	20	.5443	.4947	20	.5896	.5089
30	.3727	.3531	30	.5079	.4576	30	.5758	.4943
40	.1456	.1252	40	.4726	.4215	40	.5622	.4800
50	5.9342	5.9131	50	.4382	.3864	50	.5489	.4659
5 00	5.7369	5.7150	12 00	2.4049	2.3523	19 00	1.5358	1.4521
10	.5523	.5297	10	.3724	.3191	10	.5229	.4385
20	.3792	.3560	20	.3408	.2868	20	.5103	.4251
30	.2167	.1927	30	.3101	.2554	30	.4979	.4120
40	.0638	.0390	40	.2802	.2247	40	.4857	.3990
50	4.9196	4.8941	50	.2511	.1948	50	.4737	.3863
6 00	4.7834	4.7572	13 00	2.2227	2.1657	20 00	1.4619	1.3737
10	.6546	.6277	10	.1951	.1374	30	.4277	.3373
20	.5326	.5049	20	.1681	.1097	21 00	.3952	.3025
30	.4168	.3884	30	.1418	.0826	30	.3643	.2693
40	.3069	.2778	40	.1162	.0563	22 00	.3347	.2375
50	.2023	.1725	50	.0912	.0305	30	.3066	.2071
						23 00	.2797	.1779
7 00	4.1028	4.0722	14 00	2.0668	2.0054	30	.2539	.1499
10	.0078	3.9765	10	.0430	1.9808	24 00	.2293	.1230
20	3.9172	.8852	20	.0197	.9568	30	.2057	.0971
30	.8306	.7979	30	1.9970	.9334			
40	.7479	.7144	40	.9748	.9104	25 00	1.1831	1.0723
50	.6686	.6344	50	.9531	.8880	30	.1614	.0483

TABLE 18.—Natural half-cosecants and half-cotangents—Continued

Angle ° ′	½ cosec	½ cot
26 00	1.1406	1.0252
30	.1206	.0028
27 00	.1013	0.9813
30	.0828	.9605
28 00	.0650	.9404
30	.0479	.9209
29 00	.0313	.9020
30	.0154	.8837
30 00	1.0000	0.8660
30	0.9851	.8488
31 00	.9708	.8321
30	.9569	.8159
32 00	.9435	.8002
30	.9306	.7848
33 00	.9180	.7699
30	.9059	.7554
34 00	.8941	.7413
30	.8828	.7275
35 00	0.8717	0.7141
30	.8610	.7010
36 00	.8507	.6882
30	.8406	.6757
37 00	.8308	.6635
30	.8213	.6516
38 00	.8121	.6400
30	.8032	.6286
39 00	.7945	.6174
30	.7861	.6065
40 00	0.7779	0.5959
30	.7699	.5854
41 00	.7621	.5752

Angle ° ′	½ cosec	½ cot
41 30	0.7546	0.5651
42 00	.7472	.5553
30	.7401	.5457
43 00	.7331	.5362
30	.7264	.5269
44 00	.7198	.5178
30	.7134	.5088
45 00	0.7071	0.5000
30	.7010	.4913
46 00	.6951	.4828
30	.6893	.4745
47 00	.6837	.4663
30	.6782	.4582
48 00	.6728	.4502
30	.6676	.4424
49 00	.6625	.4346
30	.6575	.4270
50 00	0.6527	0.4195
51 00	.6434	.4049
52 00	.6345	.3906
53 00	.6261	.3768
54 00	.6180	.3633
55 00	0.6104	0.3501
56 00	.6031	.3373
57 00	.5962	.3247
58 00	.5896	.3124
59 00	.5833	.3004
60 00	0.5774	0.2887
61 00	.5717	.2772
62 00	.5663	.2659

Angle ° ′	½ cosec	½ cot
63 00	0.5612	0.2548
64 00	.5563	.2439
65 00	.5517	.2332
66 00	.5473	.2226
67 00	.5432	.2122
68 00	.5393	.2020
69 00	.5356	.1919
70 00	0.5321	0.1820
71 00	.5288	.1722
72 00	.5257	.1625
73 00	.5228	.1529
74 00	.5201	.1434
75 00	.5176	.1340
76 00	.5153	.1247
77 00	.5132	.1154
78 00	.5112	.1063
79 00	.5094	.0972
80 00	0.5077	0.0882
81 00	.5062	.0792
82 00	.5049	.0703
83 00	.5038	.0614
84 00	.5028	.0526
85 00	.5019	.0437
86 00	.5012	.0350
87 00	.5007	.0262
88 00	.5003	.0175
89 00	.5001	.0087
90 00	0.5000	0.0000

7–32 Miscellaneous conversion tables.—For miscellaneous use several conversion tables are included which have various applications in hydrographic surveying.

TABLE 19.—Linear distance conversion—fathoms-meters-feet-yards

	Fathoms to —		Meters to —			Feet to —		Yards to —
	Feet	Meters	Fathoms	Yards	Feet	Meters	Fathoms	Meters
1	6	1.82880	0.54681	1.09361	3.28083	0.30480	0.16667	0.91440
2	12	3.65761	1.09361	2.18722	6.56167	0.60960	0.33333	1.82880
3	18	5.48641	1.64042	3.28083	9.84250	0.91440	0.50000	2.74320
4	24	7.31521	2.18722	4.37444	13.12333	1.21920	0.66667	3.65761
5	30	9.14402	2.73403	5.46806	16.40417	1.52400	0.83333	4.57201
6	36	10.97282	3.28083	6.56167	19.68500	1.82880	1.00000	5.48641
7	42	12.80163	3.82764	7.65528	22.96583	2.13360	1.16667	6.40081
8	48	14.63043	4.37444	8.74889	26.24667	2.43840	1.33333	7.31521
9	54	16.45923	4.92125	9.84250	29.52750	2.74320	1.50000	8.22962

TABLE 20.—Linear distance conversion-nautical miles-statute miles-kilometers

	Nautical miles to —		Statute miles to —		Kilometers to —	
	Statute miles	Kilometers	Nautical miles	Kilometers	Statute miles	Nautical miles
1	1.15078	1.85200	0.86898	1.60935	0.62137	0.53996
2	2.30155	3.70400	1.73796	3.21869	1.24274	1.07991
3	3.45233	5.55600	2.60693	4.82804	1.86411	1.61987
4	4.60311	7.40800	3.47591	6.43739	2.48548	2.15983
5	5.75389	9.26000	4.34489	8.04674	3.10685	2.69978
6	6.90466	11.11200	5.21387	9.65608	3.72822	3.23974
7	8.05544	12.96400	6.08285	11.26543	4.34959	3.77970
8	9.20622	14.81600	6.95182	12.87478	4.97096	4.31965
9	10.35699	16.66800	7.82080	14.48412	5.59233	4.85961

TABLE 21.—Temperature conversion

CENTIGRADE TO FAHRENHEIT

°C.	°F.	°C.	°F.	°C.	°F.	°C.	°F.	°C.	°F.
−2	28.4	5	41.0	12	53.6	19	66.2	26	78.8
−1	30.2	6	42.8	13	55.4	20	68.0	27	80.6
0	32.0	7	44.6	14	57.2	21	69.8	28	82.4
1	33.8	8	46.4	15	59.0	22	71.6	29	84.2
2	35.6	9	48.2	16	60.8	23	73.4	30	86.0
3	37.4	10	50.0	17	62.6	24	75.2	31	87.8
4	39.2	11	51.8	18	64.4	25	77.0	32	89.6

FAHRENHEIT TO CENTIGRADE

°F.	°C.	°F.	°C.	°F.	°C.	°F.	°C.	°F.	°C.
28	−2.2	41	5.0	54	12.2	67	19.4	80	26.7
29	−1.7	42	5.6	55	12.8	68	20.0	81	27.2
30	−1.1	43	6.1	56	13.3	69	20.6	82	27.8
31	−0.6	44	6.7	57	13.9	70	21.1	83	28.3
32	0.0	45	7.2	58	14.4	71	21.7	84	28.9
33	+0.6	46	7.8	59	15.0	72	22.2	85	29.4
34	1.1	47	8.3	60	15.6	73	22.8	86	30.0
35	1.7	48	8.9	61	16.1	74	23.3	87	30.6
36	2.2	49	9.4	62	16.7	75	23.9	88	31.1
37	2.8	50	10.0	63	17.2	76	24.4	89	31.7
38	3.3	51	10.6	64	17.8	77	25.0	90	32.2
39	3.9	52	11.1	65	18.3	78	25.6		
40	4.4	53	11.7	66	18.9	79	26.1		

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